

	1100010100_1000111010	// W0668_2048 = -0.460539	-0.887640
	1100010011_1000111010	// W0669_2048 = -0.463260	-0.886223
	1100010001_1000111011	// W0670_2048 = -0.465976	-0.884797
	1100001111_1000111100	// W0672_2048 = -0.471397	-0.881921
5	1100001100_1000111110	// W0674_2048 = -0.476799	-0.879012
	1100001010_1000111111	// W0675_2048 = -0.479494	-0.877545
	1100001001_1000111111	// W0676_2048 = -0.482184	-0.876070
	1100000110_1001000001	// W0678_2048 = -0.487550	-0.873095
	1100000100_1001000011	// W0680_2048 = -0.492898	-0.870087
10	1100000010_1001000011	// W0681_2048 = -0.495565	-0.868571
	1100000001_1001000100	// W0682_2048 = -0.498228	-0.867046
	1011111110_1001000110	// W0684_2048 = -0.503538	-0.863973
	1011111101_1001000111	// W0685_2048 = -0.508830	-0.860867
	10111111010_1001001000	// W0687_2048 = -0.511469	-0.859302
15	10111111001_1001001001	// W0688_2048 = -0.514103	-0.857729
	1011110110_1001001010	// W0690_2048 = -0.519356	-0.854558
	1011110011_1001001100	// W0692_2048 = -0.524590	-0.851355
	1011110010_1001001101	// W0693_2048 = -0.527199	-0.849742
	1011110001_1001001110	// W0694_2048 = -0.529804	-0.848120
20	1011110110_1001001111	// W0696_2048 = -0.534998	-0.844854
	1011101011_1001010001	// W0698_2048 = -0.540171	-0.841555
	1011101010_1001010010	// W0699_2048 = -0.542751	-0.839894
	1011101001_1001010011	// W0700_2048 = -0.545325	-0.838225
	1011100110_1001010101	// W0702_2048 = -0.550458	-0.834863
25	1011100100_1001010110	// W0704_2048 = -0.555570	-0.831470
	1011100010_1001010111	// W0705_2048 = -0.558119	-0.829761
	1011100001_1001011000	// W0706_2048 = -0.560662	-0.828045
	1011011110_1001011010	// W0708_2048 = -0.565732	-0.824589
	10110111100_1001011100	// W0710_2048 = -0.570781	-0.821103
30	10110111010_1001011100	// W0711_2048 = -0.573297	-0.819348
	1011011001_1001011101	// W0712_2048 = -0.575808	-0.817585
	1011010111_1001011111	// W0714_2048 = -0.580814	-0.814036
	1011010100_1001100001	// W0716_2048 = -0.585798	-0.810457
	1011010011_1001100010	// W0717_2048 = -0.588282	-0.808656
35	1011010010_1001100011	// W0718_2048 = -0.590760	-0.806848
	1011001111_1001100101	// W0720_2048 = -0.595699	-0.803208
	1011001100_1001100111	// W0722_2048 = -0.600616	-0.799537
	1011001011_1001101000	// W0723_2048 = -0.603067	-0.797691
	1011001010_1001101001	// W0724_2048 = -0.605511	-0.795837
40	1011000111_1001101010	// W0726_2048 = -0.610383	-0.792107
	1011000101_1001101100	// W0728_2048 = -0.615232	-0.788346
	1011000100_1001101101	// W0729_2048 = -0.617647	-0.786455
	1011000011_1001101110	// W0730_2048 = -0.620057	-0.784557
	1011000000_1001110000	// W0732_2048 = -0.624859	-0.780737
45	1010111110_1001110010	// W0734_2048 = -0.629638	-0.776888
	1010111100_1001110011	// W0735_2048 = -0.632019	-0.774953
	1010111011_1001110100	// W0736_2048 = -0.634393	-0.773010
	1010111001_1001110110	// W0738_2048 = -0.639124	-0.769103
	1010110110_1001111000	// W0740_2048 = -0.643832	-0.765167
50	1010110101_1001111001	// W0741_2048 = -0.646176	-0.763188
	1010110100_1001111010	// W0742_2048 = -0.648514	-0.761202
	1010110010_1001111100	// W0744_2048 = -0.653173	-0.757209
	1010101111_1001111110	// W0746_2048 = -0.657807	-0.753187
	1010101110_1001111111	// W0747_2048 = -0.660114	-0.751165
55	1010101101_1010000000	// W0748_2048 = -0.662416	-0.749136
	1010101010_1010000011	// W0750_2048 = -0.667000	-0.745058

	1110010000_1000001100	// W0584_2048 = -0.219101	-0.975702
	1110001110_1000001101	// W0585_2048 = -0.222094	-0.975025
	1110001101_1000001101	// W0586_2048 = -0.225084	-0.974339
	1110001010_1000001110	// W0588_2048 = -0.231058	-0.972940
5	1110000111_1000001111	// W0590_2048 = -0.237024	-0.971504
	1110000101_1000001111	// W0591_2048 = -0.240003	-0.970772
	1110000100_1000001111	// W0592_2048 = -0.242980	-0.970031
	1110000001_1000010000	// W0594_2048 = -0.248928	-0.968522
10	1101111110_1000010001	// W0596_2048 = -0.254866	-0.966976
	1101111100_1000010001	// W0597_2048 = -0.257831	-0.966190
	1101111010_1000010010	// W0598_2048 = -0.260794	-0.965394
	1101110111_1000010011	// W0600_2048 = -0.266713	-0.963776
	1101110100_1000010011	// W0602_2048 = -0.272621	-0.962121
15	1101110011_1000010100	// W0603_2048 = -0.275572	-0.961280
	1101110001_1000010100	// W0604_2048 = -0.278520	-0.960431
	1101101110_1000010101	// W0606_2048 = -0.284408	-0.958703
	1101101011_1000010110	// W0608_2048 = -0.290285	-0.956940
	1101101010_1000010111	// W0609_2048 = -0.293219	-0.956045
	1101101000_1000010111	// W0610_2048 = -0.296151	-0.955141
20	1101100101_1000011000	// W0612_2048 = -0.302006	-0.953306
	1101100010_1000011001	// W0614_2048 = -0.307850	-0.951435
	1101100001_1000011001	// W0615_2048 = -0.310767	-0.950486
	1101011111_1000011010	// W0616_2048 = -0.313682	-0.949528
	1101011100_1000011011	// W0618_2048 = -0.319502	-0.947586
25	1101011001_1000011100	// W0620_2048 = -0.325310	-0.945607
	1101011000_1000011100	// W0621_2048 = -0.328210	-0.944605
	1101010110_1000011101	// W0622_2048 = -0.331106	-0.943593
	1101010100_1000011110	// W0624_2048 = -0.336890	-0.941544
	1101010001_1000011111	// W0626_2048 = -0.342661	-0.939459
30	1101001111_1000100000	// W0627_2048 = -0.345541	-0.938404
	1101001110_1000100000	// W0628_2048 = -0.348419	-0.937339
	1101001011_1000100001	// W0630_2048 = -0.354164	-0.935184
	1101001000_1000100010	// W0632_2048 = -0.359895	-0.932993
	1101000110_1000100011	// W0633_2048 = -0.362756	-0.931884
35	1101000101_1000100011	// W0634_2048 = -0.365613	-0.930767
	1101000010_1000100101	// W0636_2048 = -0.371317	-0.928506
	1100111111_1000100110	// W0638_2048 = -0.377007	-0.926210
	1100111110_1000100110	// W0639_2048 = -0.379847	-0.925049
	1100111100_1000100111	// W0640_2048 = -0.382683	-0.923880
40	1100111001_1000101000	// W0642_2048 = -0.388345	-0.921514
	1100110110_1000101001	// W0644_2048 = -0.393992	-0.919114
	1100110101_1000101010	// W0645_2048 = -0.396810	-0.917901
	1100110011_1000101011	// W0646_2048 = -0.399624	-0.916679
	1100110001_1000101100	// W0648_2048 = -0.405241	-0.914210
45	1100101110_1000101101	// W0650_2048 = -0.410843	-0.911706
	1100101100_1000101110	// W0651_2048 = -0.413638	-0.910441
	1100101011_1000101111	// W0652_2048 = -0.416430	-0.909168
	1100101000_1000110000	// W0654_2048 = -0.422000	-0.906596
	1100100101_1000110001	// W0656_2048 = -0.427555	-0.903989
50	1100100100_1000110010	// W0657_2048 = -0.430326	-0.902673
	1100100010_1000110011	// W0658_2048 = -0.433094	-0.901349
	1100011111_1000110100	// W0660_2048 = -0.438616	-0.898674
	1100011101_1000110101	// W0662_2048 = -0.444122	-0.895966
	1100011011_1000110110	// W0663_2048 = -0.446869	-0.894599
55	1100011010_1000110111	// W0664_2048 = -0.449611	-0.893224
	1100010111_1000111000	// W0666_2048 = -0.455084	-0.890449

	0000001101_10000_000 // W0504_2048 = +0.024541	-0.999699
	0000001011_10000_000 // W0505_2048 = +0.021474	-0.999769
	0000001001_1000000000 // W0506_2048 = +0.018407	-0.999831
	0000001000_1000000000 // W0507_2048 = +0.015339	-0.999882
5	0000000110_1000000000 // W0508_2048 = +0.012272	-0.999925
	0000000101_1000000000 // W0509_2048 = +0.009204	-0.999958
	0000000011_1000000000 // W0510_2048 = +0.006136	-0.999981
	0000000010_1000000000 // W0511_2048 = +0.003068	-0.999995
	0000000000_1000000000 // W0512_2048 = +0.000000	-1.000000
10	1111111110_1000000000 // W0513_2048 = -0.003068	-0.999995
	1111111101_1000000000 // W0514_2048 = -0.006136	-0.999981
	1111111010_1000000000 // W0516_2048 = -0.012272	-0.999925
	1111110111_1000000000 // W0513_2048 = -0.013407	-0.999831
	1111110101_1000000000 // W0519_2048 = -0.021474	-0.999769
15	1111110011_1000000000 // W0520_2048 = -0.024541	-0.999699
	1111110000_1000000000 // W0522_2048 = -0.030675	-0.999529
	1111101101_1000000000 // W0524_2048 = -0.036807	-0.999322
	1111101100_1000000000 // W0525_2048 = -0.039873	-0.999205
	1111101010_1000000000 // W0526_2048 = -0.042938	-0.999078
20	1111100111_1000000001 // W0528_2048 = -0.049068	-0.998795
	1111100100_1000000001 // W0530_2048 = -0.055195	-0.998476
	1111100010_1000000001 // W0531_2048 = -0.058258	-0.998302
	1111100001_1000000001 // W0532_2048 = -0.061321	-0.998118
	1111011101_1000000001 // W0534_2048 = -0.067444	-0.997723
25	1111011010_1000000001 // W0536_2048 = -0.073565	-0.997290
	1111011001_1000000010 // W0537_2048 = -0.076624	-0.997060
	1111010111_1000000010 // W0538_2048 = -0.079682	-0.996820
	1111010100_1000000010 // W0540_2048 = -0.085797	-0.996313
	1111010001_1000000010 // W0542_2048 = -0.091909	-0.995767
30	1111001111_1000000010 // W0543_2048 = -0.094963	-0.995481
	1111001110_1000000010 // W0544_2048 = -0.098017	-0.995185
	1111001011_1000000011 // W0546_2048 = -0.104122	-0.994565
	1111001000_1000000011 // W0548_2048 = -0.110222	-0.993907
	1111000110_1000000011 // W0549_2048 = -0.113271	-0.993564
35	1111000100_1000000011 // W0550_2048 = -0.116319	-0.993212
	1111000001_1000000100 // W0552_2048 = -0.122411	-0.992480
	1110111110_1000000100 // W0554_2048 = -0.128498	-0.991710
	1110111101_1000000100 // W0555_2048 = -0.131540	-0.991311
	1110111011_1000000101 // W0556_2048 = -0.134581	-0.990903
40	1110111000_1000000101 // W0558_2048 = -0.140658	-0.990058
	1110110101_1000000110 // W0560_2048 = -0.146730	-0.989177
	1110110011_1000000110 // W0561_2048 = -0.149765	-0.988722
	1110110010_1000000110 // W0562_2048 = -0.152797	-0.988258
	1110101111_1000000111 // W0564_2048 = -0.158858	-0.987301
45	1110101100_1000000111 // W0566_2048 = -0.164913	-0.986308
	1110101010_1000000111 // W0567_2048 = -0.167938	-0.985798
	1110101000_1000001000 // W0568_2048 = -0.170962	-0.985278
	1110100101_1000001000 // W0570_2048 = -0.177004	-0.984210
	1110100010_1000001001 // W0572_2048 = -0.183040	-0.983105
50	1110100001_1000001001 // W0573_2048 = -0.186055	-0.982539
	1110011111_1000001001 // W0574_2048 = -0.189069	-0.981964
	1110011100_1000001010 // W0576_2048 = -0.195090	-0.980785
	1110011001_1000001010 // W0578_2048 = -0.201105	-0.979570
	1110010111_1000001011 // W0579_2048 = -0.204109	-0.978948
55	1110010110_1000001011 // W0580_2048 = -0.207111	-0.978317
	1110010011_1000001100 // W0582_2048 = -0.213110	-0.977028

	0001100100_1000001010	// W0448_2048 = +0.195090	-0.980785
	0001100010_1000001010	// W0449_2048 = +0.192080	-0.981379
	0001100001_1000001001	// W0450_2048 = +0.189069	-0.981964
	0001011111_1000001001	// W0451_2048 = +0.186055	-0.982539
5	0001011110_1000001001	// W0452_2048 = +0.183040	-0.983105
	0001011100_1000001000	// W0453_2048 = +0.180023	-0.983662
	0001011011_1000001000	// W0454_2048 = +0.177004	-0.984210
	0001011001_1000001000	// W0455_2048 = +0.173984	-0.984749
	0001011000_1000001000	// W0456_2048 = +0.170962	-0.985278
10	0001010110_1000000111	// W0457_2048 = +0.167938	-0.985798
	0001010100_1000000111	// W0458_2048 = +0.164913	-0.986308
	0001010011_1000000111	// W0459_2048 = +0.161886	-0.986809
	0001010001_1000000111	// W0460_2048 = +0.158858	-0.987301
	0001010000_1000000110	// W0461_2048 = +0.155828	-0.987784
15	0001001110_1000000110	// W0462_2048 = +0.152797	-0.988258
	0001001101_1000000110	// W0463_2048 = +0.149765	-0.988722
	0001001011_1000000110	// W0464_2048 = +0.146730	-0.989177
	0001001010_1000000101	// W0465_2048 = +0.143695	-0.989622
	0001001000_1000000101	// W0466_2048 = +0.140658	-0.990058
20	0001000110_1000000101	// W0467_2048 = +0.137620	-0.990485
	0001000101_1000000101	// W0468_2048 = +0.134581	-0.990903
	0001000011_1000000100	// W0469_2048 = +0.131540	-0.991311
	0001000010_1000000100	// W0470_2048 = +0.128498	-0.991710
	0001000000_1000000100	// W0471_2048 = +0.125455	-0.992099
25	0000111111_1000000100	// W0472_2048 = +0.122411	-0.992480
	0000111101_1000000100	// W0473_2048 = +0.119365	-0.992850
	0000111100_1000000011	// W0474_2048 = +0.116319	-0.993212
	0000111010_1000000011	// W0475_2048 = +0.113271	-0.993564
	0000111000_1000000011	// W0476_2048 = +0.110222	-0.993907
30	0000110111_1000000011	// W0477_2048 = +0.107172	-0.994240
	0000110101_1000000011	// W0478_2048 = +0.104122	-0.994565
	0000110100_1000000011	// W0479_2048 = +0.101070	-0.994879
	0000110010_1000000010	// W0480_2048 = +0.098017	-0.995185
	0000110001_1000000010	// W0481_2048 = +0.094963	-0.995481
35	0000101111_1000000010	// W0482_2048 = +0.091909	-0.995767
	0000101101_1000000010	// W0483_2048 = +0.088854	-0.996045
	0000101100_1000000010	// W0484_2048 = +0.085797	-0.996313
	0000101010_1000000010	// W0485_2048 = +0.082740	-0.996571
	0000101001_1000000010	// W0486_2048 = +0.079682	-0.996820
40	0000100111_1000000010	// W0487_2048 = +0.076624	-0.997060
	0000100110_1000000001	// W0488_2048 = +0.073565	-0.997290
	0000100100_1000000001	// W0489_2048 = +0.070505	-0.997511
	0000100011_1000000001	// W0490_2048 = +0.067444	-0.997723
	0000100001_1000000001	// W0491_2048 = +0.064383	-0.997925
45	0000011111_1000000001	// W0492_2048 = +0.061321	-0.998118
	0000011110_1000000001	// W0493_2048 = +0.058258	-0.998302
	0000011100_1000000001	// W0494_2048 = +0.055195	-0.998476
	0000011011_1000000001	// W0495_2048 = +0.052132	-0.998640
	0000011001_1000000001	// W0496_2048 = +0.049068	-0.998795
50	0000011000_1000000001	// W0497_2048 = +0.046003	-0.998941
	0000010110_1000000000	// W0498_2048 = +0.042938	-0.999078
	0000010100_1000000000	// W0499_2048 = +0.039873	-0.999205
	0000010011_1000000000	// W0500_2048 = +0.036807	-0.999322
	0000010001_1000000000	// W0501_2048 = +0.033741	-0.999431
55	0000010000_1000000000	// W0502_2048 = +0.030675	-0.999529
	0000001110_1000000000	// W0503_2048 = +0.027608	-0.999619

	0010111000_1000100010	// W0392_2048 = +0.359895	-0.932993
	0010110111_1000100010	// W0393_2048 = +0.357031	-0.934093
	0010110101_1000100001	// W0394_2048 = +0.354164	-0.935184
	0010110100_1000100001	// W0395_2048 = +0.351293	-0.936266
5	0010110010_1000100000	// W0396_2048 = +0.348419	-0.937339
	0010110001_1000100000	// W0397_2048 = +0.345541	-0.938404
	0010101111_1000011111	// W0398_2048 = +0.342661	-0.939459
	0010101110_1000011110	// W0399_2048 = +0.339777	-0.940506
	0010101100_1000011110	// W0400_2048 = +0.336890	-0.941544
10	0010101011_1000011101	// W0401_2048 = +0.334000	-0.942573
	0010101010_1000011101	// W0402_2048 = +0.331106	-0.943593
	0010101000_1000011100	// W0403_2048 = +0.328210	-0.944605
	0010100111_1000011100	// W0404_2048 = +0.325310	-0.945607
	0010100101_1000011011	// W0405_2048 = +0.322408	-0.946601
15	0010100100_1000011011	// W0406_2048 = +0.319502	-0.947586
	0010100010_1000011010	// W0407_2048 = +0.316593	-0.948561
	0010100001_1000011010	// W0408_2048 = +0.313682	-0.949528
	0010011111_1000011001	// W0409_2048 = +0.310767	-0.950486
	0010011110_1000011001	// W0410_2048 = +0.307850	-0.951435
20	0010011100_1000011000	// W0411_2048 = +0.304929	-0.952375
	0010011011_1000011000	// W0412_2048 = +0.302006	-0.953306
	0010011001_1000010111	// W0413_2048 = +0.299080	-0.954228
	0010011000_1000010111	// W0414_2048 = +0.296151	-0.955141
	0010010110_1000010111	// W0415_2048 = +0.293219	-0.956045
25	0010010101_1000010110	// W0416_2048 = +0.290285	-0.956940
	0010010011_1000010110	// W0417_2048 = +0.287347	-0.957826
	0010010010_1000010101	// W0418_2048 = +0.284408	-0.958703
	0010010000_1000010101	// W0419_2048 = +0.281465	-0.959572
	0010001111_1000010100	// W0420_2048 = +0.278520	-0.960431
30	0010001101_1000010100	// W0421_2048 = +0.275572	-0.961280
	0010001100_1000010011	// W0422_2048 = +0.272621	-0.962121
	0010001010_1000010011	// W0423_2048 = +0.269668	-0.962953
	0010001001_1000010011	// W0424_2048 = +0.266713	-0.963776
	0010000111_1000010010	// W0425_2048 = +0.263755	-0.964590
35	0010000110_1000010010	// W0426_2048 = +0.260794	-0.965394
	0010000100_1000010001	// W0427_2048 = +0.257831	-0.966190
	0010000010_1000010001	// W0428_2048 = +0.254866	-0.966976
	0010000001_1000010001	// W0429_2048 = +0.251898	-0.967754
	0001111111_1000010000	// W0430_2048 = +0.248928	-0.968522
40	0001111110_1000010000	// W0431_2048 = +0.245955	-0.969281
	0001111100_1000001111	// W0432_2048 = +0.242980	-0.970031
	0001111101_1000001111	// W0433_2048 = +0.240003	-0.970772
	0001111100_1000001111	// W0434_2048 = +0.237024	-0.971504
	0001111100_1000001110	// W0435_2048 = +0.234042	-0.972226
45	0001110110_1000001110	// W0436_2048 = +0.231058	-0.972940
	0001110101_1000001101	// W0437_2048 = +0.228072	-0.973644
	0001110011_1000001101	// W0438_2048 = +0.225084	-0.974339
	0001110010_1000001101	// W0439_2048 = +0.222094	-0.975025
	0001110000_1000001100	// W0440_2048 = +0.219101	-0.975702
50	0001101111_1000001100	// W0441_2048 = +0.216107	-0.976370
	0001101101_1000001100	// W0442_2048 = +0.213110	-0.977028
	0001101000_1000001011	// W0443_2048 = +0.210112	-0.977677
	0001101010_1000001011	// W0444_2048 = +0.207111	-0.978317
	0001101001_1000001011	// W0445_2048 = +0.204109	-0.978948
55	0001100111_1000001010	// W0446_2048 = +0.201105	-0.979570
	0001100101_1000001010	// W0447_2048 = +0.198098	-0.980182

	0100000111_1001001001	// W0336_2048 = +0.514103	-0.857729
	0100000110_1001001000	// W0337_2048 = +0.511469	-0.859302
	0100000101_1001000111	// W0338_2048 = +0.508830	-0.860867
	0100000011_1001000110	// W0339_2048 = +0.506187	-0.862424
5	0100000010_1001000110	// W0340_2048 = +0.503538	-0.863973
	0100000000_1001000101	// W0341_2048 = +0.500885	-0.865514
	0011111111_1001000100	// W0342_2048 = +0.498228	-0.867046
	0011111110_1001000011	// W0343_2048 = +0.495565	-0.868571
	0011111100_1001000011	// W0344_2048 = +0.492898	-0.870087
10	0011111011_1001000010	// W0345_2048 = +0.490226	-0.871595
	0011111010_1001000001	// W0346_2048 = +0.487550	-0.873095
	0011111000_1001000000	// W0347_2048 = +0.484869	-0.874587
	0011110111_1000111111	// W0348_2048 = +0.482184	-0.876070
	0011110110_1000111111	// W0349_2048 = +0.479494	-0.877545
15	0011110100_1000111110	// W0350_2048 = +0.476799	-0.879012
	0011110011_1000111101	// W0351_2048 = +0.474100	-0.880471
	0011110001_1000111100	// W0352_2048 = +0.471397	-0.881921
	0011110000_1000111100	// W0353_2048 = +0.468689	-0.883363
	0011101111_1000111011	// W0354_2048 = +0.465976	-0.884797
20	0011101101_1000111010	// W0355_2048 = +0.463260	-0.886223
	0011101100_1000111010	// W0356_2048 = +0.460539	-0.887640
	0011101010_1000111001	// W0357_2048 = +0.457813	-0.889048
	0011101001_1000111000	// W0358_2048 = +0.455084	-0.890449
	0011101000_1000110111	// W0359_2048 = +0.452350	-0.891841
25	0011100110_1000110111	// W0360_2048 = +0.449611	-0.893224
	0011100101_1000110110	// W0361_2048 = +0.446869	-0.894599
	0011100011_1000110101	// W0362_2048 = +0.444122	-0.895966
	0011100010_1000110101	// W0363_2048 = +0.441371	-0.897325
	0011100001_1000110100	// W0364_2048 = +0.438616	-0.898674
30	0011011111_1000110011	// W0365_2048 = +0.435857	-0.900016
	0011011110_1000110011	// W0366_2048 = +0.433094	-0.901349
	0011011100_1000110010	// W0367_2048 = +0.430326	-0.902673
	0011011011_1000110001	// W0368_2048 = +0.427555	-0.903989
	0011011001_1000110000	// W0369_2048 = +0.424780	-0.905297
35	0011011000_1000110000	// W0370_2048 = +0.422000	-0.906596
	0011010111_1000101111	// W0371_2048 = +0.419217	-0.907886
	0011010101_1000101111	// W0372_2048 = +0.416430	-0.909168
	0011010100_1000101110	// W0373_2048 = +0.413638	-0.910441
	0011010010_1000101101	// W0374_2048 = +0.410843	-0.911706
40	0011010001_1000101101	// W0375_2048 = +0.408044	-0.912962
	0011001111_1000101100	// W0376_2048 = +0.405241	-0.914210
	0011001110_1000101011	// W0377_2048 = +0.402435	-0.915449
	0011001101_1000101011	// W0378_2048 = +0.399624	-0.916679
	0011001011_1000101010	// W0379_2048 = +0.396810	-0.917901
45	0011001010_1000101001	// W0380_2048 = +0.393992	-0.919114
	0011001000_1000101001	// W0381_2048 = +0.391170	-0.920318
	0011000111_1000101000	// W0382_2048 = +0.388345	-0.921514
	0011000101_1000101000	// W0383_2048 = +0.385516	-0.922701
	0011000100_1000100111	// W0384_2048 = +0.382683	-0.923880
50	0011000010_1000100110	// W0385_2048 = +0.379847	-0.925049
	0011000001_1000100110	// W0386_2048 = +0.377007	-0.926210
	0011000000_1000100101	// W0387_2048 = +0.374164	-0.927363
	0010111110_1000100101	// W0388_2048 = +0.371317	-0.928506
	0010111101_1000100100	// W0389_2048 = +0.368467	-0.929641
55	0010111011_1000100011	// W0390_2048 = +0.365613	-0.930767
	0010111010_1000100011	// W0391_2048 = +0.362756	-0.931884

	0101001110_1001111100	// W0280_2048 = +0.153173	-0.157209
	0101001101_1001111011	// W0281_2048 = +0.650847	-0.759209
	0101001100_1001111010	// W0282_2048 = +0.648514	-0.761202
	0101001011_1001111001	// W0283_2048 = +0.646176	-0.763188
5	0101001010_1001111000	// W0284_2048 = +0.643832	-0.765167
	0101001000_1001111011	// W0285_2048 = +0.641481	-0.767139
	0101000111_1001111010	// W0286_2048 = +0.639124	-0.769103
	0101000110_1001111011	// W0287_2048 = +0.636762	-0.771061
	0101000101_10011110100	// W0288_2048 = +0.634393	-0.773010
10	0101000100_10011110011	// W0289_2048 = +0.632019	-0.774953
	0101000010_10011110010	// W0290_2048 = +0.629638	-0.776888
	0101000001_10011110001	// W0291_2048 = +0.627252	-0.778817
	0101000000_10011110000	// W0292_2048 = +0.624859	-0.780737
	0100111111_1001101111	// W0293_2048 = +0.622461	-0.782651
15	0100111101_1001101110	// W0294_2048 = +0.620057	-0.784557
	0100111100_1001101101	// W0295_2048 = +0.617647	-0.786455
	0100111011_1001101100	// W0296_2048 = +0.615232	-0.788346
	0100111010_1001101011	// W0297_2048 = +0.612810	-0.790230
	0100111001_1001101010	// W0298_2048 = +0.610383	-0.792107
20	0100110111_1001101001	// W0299_2048 = +0.607950	-0.793975
	0100110110_1001101001	// W0300_2048 = +0.605511	-0.795837
	0100110101_1001101000	// W0301_2048 = +0.603067	-0.797691
	0100110100_1001100111	// W0302_2048 = +0.600616	-0.799537
	0100110010_1001100110	// W0303_2048 = +0.598161	-0.801376
25	0100110001_1001100101	// W0304_2048 = +0.595699	-0.803208
	0100110000_1001100100	// W0305_2048 = +0.593232	-0.805031
	0100101110_1001100011	// W0306_2048 = +0.590760	-0.806848
	0100101101_1001100010	// W0307_2048 = +0.588282	-0.808656
	0100101100_1001100001	// W0308_2048 = +0.585798	-0.810457
30	0100101011_1001100000	// W0309_2048 = +0.583309	-0.812251
	0100101001_1001011111	// W0310_2048 = +0.580814	-0.814036
	0100101000_1001011110	// W0311_2048 = +0.578314	-0.815814
	0100100111_1001011101	// W0312_2048 = +0.575808	-0.817585
	0100100110_1001011100	// W0313_2048 = +0.573297	-0.819348
35	0100100100_1001011100	// W0314_2048 = +0.570781	-0.821103
	0100100011_1001011011	// W0315_2048 = +0.568259	-0.822850
	0100100010_1001011010	// W0316_2048 = +0.565732	-0.824589
	0100100000_1001011001	// W0317_2048 = +0.563199	-0.826321
	0100011111_1001011000	// W0318_2048 = +0.560662	-0.828045
40	0100011110_1001010111	// W0319_2048 = +0.558119	-0.829761
	0100011100_1001010110	// W0320_2048 = +0.555570	-0.831470
	0100011011_1001010101	// W0321_2048 = +0.553017	-0.833170
	0100011010_1001010101	// W0322_2048 = +0.550458	-0.834863
	0100011001_1001010100	// W0323_2048 = +0.547894	-0.836548
45	0100010111_1001010011	// W0324_2048 = +0.545325	-0.838225
	0100010110_1001010010	// W0325_2048 = +0.542751	-0.839894
	0100010101_1001010001	// W0326_2048 = +0.540171	-0.841555
	0100010011_1001010000	// W0327_2048 = +0.537587	-0.843208
	0100010010_1001001111	// W0328_2048 = +0.534998	-0.844854
50	0100010001_1001001111	// W0329_2048 = +0.532403	-0.846491
	0100001111_1001001110	// W0330_2048 = +0.529804	-0.848120
	0100001110_1001001101	// W0331_2048 = +0.527199	-0.849742
	0100001101_1001001100	// W0332_2048 = +0.524590	-0.851355
	0100001011_1001001011	// W0333_2048 = +0.521975	-0.852961
55	0100001010_1001001010	// W0334_2048 = +0.519356	-0.854558
	0100001001_1001001010	// W0335_2048 = +0.516732	-0.856147

	0110001100_1010111011	// W0224_2048 = +0.773010	-0.634393
	0110001011_1010111010	// W0225_2048 = +0.771061	-0.636762
	0110001010_1010111001	// W0226_2048 = +0.769103	-0.639124
	0110001001_1010111000	// W0227_2048 = +0.767139	-0.641481
5	0110001000_1010110110	// W0228_2048 = +0.765167	-0.643832
	0110000111_1010110101	// W0229_2048 = +0.763188	-0.646176
	0110000110_1010110100	// W0230_2048 = +0.761202	-0.648514
	0110000101_1010110011	// W0231_2048 = +0.759209	-0.650847
	0110000100_1010110010	// W0232_2048 = +0.757209	-0.653173
10	0110000011_1010110000	// W0233_2048 = +0.755201	-0.655493
	0110000010_1010101111	// W0234_2048 = +0.753187	-0.657807
	0110000001_1010101110	// W0235_2048 = +0.751165	-0.660114
	0110000000_1010101101	// W0236_2048 = +0.749136	-0.662416
	0101111111_1010101100	// W0237_2048 = +0.747101	-0.664711
15	0101111101_1010101010	// W0238_2048 = +0.745058	-0.667000
	0101111100_1010101001	// W0239_2048 = +0.743008	-0.669283
	0101111011_1010101000	// W0240_2048 = +0.740951	-0.671559
	0101111010_1010100111	// W0241_2048 = +0.738887	-0.673829
	0101111001_1010100110	// W0242_2048 = +0.736817	-0.676093
20	0101111000_1010100101	// W0243_2048 = +0.734739	-0.678350
	0101110111_1010100100	// W0244_2048 = +0.732654	-0.680601
	0101110110_1010100010	// W0245_2048 = +0.730563	-0.682846
	0101110101_1010100001	// W0246_2048 = +0.728464	-0.685084
	0101110100_1010100000	// W0247_2048 = +0.726359	-0.687315
25	0101110011_1010011111	// W0248_2048 = +0.724247	-0.689541
	0101110010_1010011110	// W0249_2048 = +0.722128	-0.691759
	0101110001_1010011101	// W0250_2048 = +0.720003	-0.693971
	0101110000_1010011100	// W0251_2048 = +0.717870	-0.696177
	0101101110_1010011010	// W0252_2048 = +0.715731	-0.698376
30	0101101101_1010011001	// W0253_2048 = +0.713585	-0.700569
	0101101100_1010011000	// W0254_2048 = +0.711432	-0.702755
	0101101011_1010010111	// W0255_2048 = +0.709273	-0.704934
	0101101010_1010010110	// W0256_2048 = +0.707107	-0.707107
	0101101001_1010010101	// W0257_2048 = +0.704934	-0.709273
35	0101101000_1010010100	// W0258_2048 = +0.702755	-0.711432
	0101100111_1010010011	// W0259_2048 = +0.700569	-0.713585
	0101100110_1010010010	// W0260_2048 = +0.698376	-0.715731
	0101100100_1010010000	// W0261_2048 = +0.696177	-0.717870
	0101100011_1010001111	// W0262_2048 = +0.693971	-0.720003
40	0101100010_1010001110	// W0263_2048 = +0.691759	-0.722128
	0101100001_1010001101	// W0264_2048 = +0.689541	-0.724247
	0101100000_1010001100	// W0265_2048 = +0.687315	-0.726359
	0101011111_1010001011	// W0266_2048 = +0.685084	-0.728464
	0101011110_1010001010	// W0267_2048 = +0.682846	-0.730563
45	0101011100_1010001001	// W0268_2048 = +0.680601	-0.732654
	0101011011_1010001000	// W0269_2048 = +0.678350	-0.734739
	0101011010_1010000111	// W0270_2048 = +0.676093	-0.736817
	0101011001_1010000110	// W0271_2048 = +0.673829	-0.738887
	0101011000_1010000101	// W0272_2048 = +0.671559	-0.740951
50	0101010111_1010000100	// W0273_2048 = +0.669283	-0.743008
	0101010110_1010000011	// W0274_2048 = +0.667000	-0.745058
	0101010100_1010000001	// W0275_2048 = +0.664711	-0.747101
	0101010011_1010000000	// W0276_2048 = +0.662416	-0.749136
	0101010010_1001111111	// W0277_2048 = +0.660114	-0.751165
55	0101010001_1001111110	// W0278_2048 = +0.657807	-0.753187
	0101010000_1001111101	// W0279_2048 = +0.655493	-0.755201

	0110111101_1100000100	// W0168_2048 = +0.870087	-0.492898
	0110111101_1100000010	// W0169_2048 = +0.868571	-0.495565
	0110111100_1100000001	// W0170_2048 = +0.867046	-0.498228
	0110111101_1100000000	// W0171_2048 = +0.865514	-0.500885
5	0110111010_1011111100	// W0172_2048 = +0.863973	-0.503538
	0110111010_1011111101	// W0173_2048 = +0.862424	-0.506187
	0110111001_1011111011	// W0174_2048 = +0.860867	-0.508830
	0110111000_1011111010	// W0175_2048 = +0.859302	-0.511469
	0110110111_1011111001	// W0176_2048 = +0.857729	-0.514103
10	0110110110_1011110111	// W0177_2048 = +0.856147	-0.516732
	0110110110_1011110110	// W0178_2048 = +0.854558	-0.519356
	0110110101_1011110101	// W0179_2048 = +0.852961	-0.521975
	0110110100_1011110011	// W0180_2048 = +0.851355	-0.524590
	0110110011_1011110010	// W0181_2048 = +0.849742	-0.527199
15	0110110010_1011110001	// W0182_2048 = +0.848120	-0.529804
	0110110001_1011101111	// W0183_2048 = +0.846491	-0.532403
	0110110001_1011101110	// W0184_2048 = +0.844854	-0.534998
	0110110000_1011101101	// W0185_2048 = +0.843208	-0.537587
	0110101111_1011101011	// W0186_2048 = +0.841555	-0.540171
20	0110101110_1011101010	// W0187_2048 = +0.839894	-0.542751
	0110101101_1011101001	// W0188_2048 = +0.838225	-0.545325
	0110101100_1011100111	// W0189_2048 = +0.836548	-0.547894
	0110101011_1011100110	// W0190_2048 = +0.834863	-0.550458
	0110101011_1011100101	// W0191_2048 = +0.833170	-0.553017
25	0110101010_1011100100	// W0192_2048 = +0.831470	-0.555570
	0110101001_1011100010	// W0193_2048 = +0.829761	-0.558119
	0110101000_1011100001	// W0194_2048 = +0.828045	-0.560662
	0110100111_1011100000	// W0195_2048 = +0.826321	-0.563199
	0110100110_1011011110	// W0196_2048 = +0.824589	-0.565732
30	0110100101_1011011101	// W0197_2048 = +0.822850	-0.568259
	0110100100_1011011100	// W0198_2048 = +0.821103	-0.570781
	0110100100_1011011010	// W0199_2048 = +0.819348	-0.573297
	0110100011_1011011001	// W0200_2048 = +0.817585	-0.575808
	0110100010_1011011000	// W0201_2048 = +0.815814	-0.578314
35	0110100001_1011010111	// W0202_2048 = +0.814036	-0.580814
	0110100000_1011010101	// W0203_2048 = +0.812251	-0.583309
	0110011111_1011010100	// W0204_2048 = +0.810457	-0.585798
	0110011110_1011010011	// W0205_2048 = +0.808656	-0.588282
	0110011101_1011010010	// W0206_2048 = +0.806848	-0.590760
40	0110011100_1011010000	// W0207_2048 = +0.805031	-0.593232
	0110011011_1011001111	// W0208_2048 = +0.803208	-0.595699
	0110011010_1011001110	// W0209_2048 = +0.801376	-0.598161
	0110011001_1011001100	// W0210_2048 = +0.799537	-0.600616
	0110011000_1011001011	// W0211_2048 = +0.797691	-0.603067
45	0110010111_1011001010	// W0212_2048 = +0.795837	-0.605511
	0110010111_1011001001	// W0213_2048 = +0.793975	-0.607950
	0110010110_1011000111	// W0214_2048 = +0.792107	-0.610383
	0110010101_1011000110	// W0215_2048 = +0.790230	-0.612810
	0110010100_1011000101	// W0216_2048 = +0.788346	-0.615232
50	0110010011_1011000100	// W0217_2048 = +0.786455	-0.617647
	0110010010_1011000011	// W0218_2048 = +0.784557	-0.620057
	0110010001_1011000001	// W0219_2048 = +0.782651	-0.622461
	0110010000_1011000000	// W0220_2048 = +0.780737	-0.624859
	0110001111_1010111111	// W0221_2048 = +0.778817	-0.627252
55	0110001110_1010111110	// W0222_2048 = +0.776888	-0.629638
	0110001101_1010111100	// W0223_2048 = +0.774953	-0.632019

	0111100010_1101010100	// W0112_2048 = +0.941544	-0.336890
	0111100010_1101010010	// W0113_2048 = +0.940506	-0.339777
	0111100001_1101010001	// W0114_2048 = +0.939459	-0.342661
	0111100000_1101001111	// W0115_2048 = +0.938404	-0.345541
5	0111100000_1101001110	// W0116_2048 = +0.937339	-0.348419
	0111011111_1101001100	// W0117_2048 = +0.936266	-0.351293
	0111011111_1101001011	// W0118_2048 = +0.935184	-0.354164
	0111011110_1101001001	// W0119_2048 = +0.934093	-0.357031
	0111011110_1101001000	// W0120_2048 = +0.932993	-0.359895
10	0111011101_1101000110	// W0121_2048 = +0.931884	-0.362756
	0111011101_1101000101	// W0122_2048 = +0.930767	-0.365613
	0111011100_1101000011	// W0123_2048 = +0.929641	-0.368457
	0111011011_1101000010	// W0124_2048 = +0.928506	-0.371317
	0111011011_1101000000	// W0125_2048 = +0.927363	-0.374164
15	0111011010_1100111111	// W0126_2048 = +0.926210	-0.377007
	0111011010_1100111110	// W0127_2048 = +0.925049	-0.379847
	0111011001_1100111100	// W0128_2048 = +0.923880	-0.382683
	0111011000_1100111011	// W0129_2048 = +0.922701	-0.385516
	0111011000_1100111001	// W0130_2048 = +0.921514	-0.388345
20	0111010111_1100111000	// W0131_2048 = +0.920318	-0.391170
	0111010111_1100110110	// W0132_2048 = +0.919114	-0.393992
	0111010110_1100110101	// W0133_2048 = +0.917901	-0.396810
	0111010101_1100110011	// W0134_2048 = +0.916679	-0.399624
	0111010101_1100110010	// W0135_2048 = +0.915449	-0.402435
25	0111010100_1100110001	// W0136_2048 = +0.914210	-0.405241
	0111010011_1100101111	// W0137_2048 = +0.912962	-0.408044
	0111010011_1100101110	// W0138_2048 = +0.911706	-0.410843
	0111010010_1100101100	// W0139_2048 = +0.910441	-0.413638
	0111010001_1100101011	// W0140_2048 = +0.909168	-0.416430
30	0111010001_1100101001	// W0141_2048 = +0.907886	-0.419217
	0111010000_1100101000	// W0142_2048 = +0.906596	-0.422000
	0111010000_1100100111	// W0143_2048 = +0.905297	-0.424780
	0111001111_1100100101	// W0144_2048 = +0.903989	-0.427555
	0111001110_1100100100	// W0145_2048 = +0.902673	-0.430326
35	0111001101_1100100010	// W0146_2048 = +0.901349	-0.433094
	0111001101_1100100001	// W0147_2048 = +0.900016	-0.435857
	0111001100_1100011111	// W0148_2048 = +0.898674	-0.438616
	0111001011_1100011110	// W0149_2048 = +0.897325	-0.441371
	0111001011_1100011101	// W0150_2048 = +0.895966	-0.444122
40	0111001010_1100011011	// W0151_2048 = +0.894599	-0.446869
	0111001001_1100011010	// W0152_2048 = +0.893224	-0.449611
	0111001001_1100011000	// W0153_2048 = +0.891841	-0.452350
	0111001000_1100010111	// W0154_2048 = +0.890449	-0.455084
	0111000111_1100010110	// W0155_2048 = +0.889048	-0.457813
45	0111000110_1100010100	// W0156_2048 = +0.887640	-0.460539
	0111000110_1100010011	// W0157_2048 = +0.886223	-0.463260
	0111000101_1100010001	// W0158_2048 = +0.884797	-0.465976
	0111000100_1100010000	// W0159_2048 = +0.883363	-0.468689
	0111000100_1100001111	// W0160_2048 = +0.881921	-0.471397
50	0111000011_1100001101	// W0161_2048 = +0.880471	-0.474100
	0111000010_1100001100	// W0162_2048 = +0.879012	-0.476799
	0111000001_1100001010	// W0163_2048 = +0.877545	-0.479494
	0111000001_1100001001	// W0164_2048 = +0.876070	-0.482184
	0111000000_1100001000	// W0165_2048 = +0.874587	-0.484869
55	0110111111_1100000110	// W0166_2048 = +0.873095	-0.487550
	0110111110_1100000101	// W0167_2048 = +0.871595	-0.490226

	0111111000_1_0101000	// W0056_2048 = +0.985278	-0.170962
	0111111000_110100111	// W0057_2048 = +0.984749	-0.173984
	0111111000_1110100101	// W0058_2048 = +0.984210	-0.177004
	0111111000_1110100100	// W0059_2048 = +0.983662	-0.180023
5	0111110111_1110100010	// W0060_2048 = +0.983105	-0.183040
	0111110111_1110100001	// W0061_2048 = +0.982539	-0.186055
	0111110111_1110011111	// W0062_2048 = +0.981964	-0.189069
	0111110110_1110011110	// W0063_2048 = +0.981379	-0.192080
	0111110110_1110011100	// W0064_2048 = +0.980785	-0.195090
10	0111110110_1110011011	// W0065_2048 = +0.980182	-0.198098
	0111110110_1110011001	// W0066_2048 = +0.979570	-0.201105
	0111110101_1110010111	// W0067_2048 = +0.978948	-0.204109
	0111110101_1110010110	// W0068_2048 = +0.978317	-0.207111
	0111110101_1110010100	// W0069_2048 = +0.977677	-0.210112
15	0111110100_1110010011	// W0070_2048 = +0.977028	-0.213110
	0111110100_1110010001	// W0071_2048 = +0.976370	-0.216107
	0111110100_1110010000	// W0072_2048 = +0.975702	-0.219101
	0111110011_1110001110	// W0073_2048 = +0.975025	-0.222094
	0111110011_1110001101	// W0074_2048 = +0.974339	-0.225084
20	0111110011_1110001011	// W0075_2048 = +0.973644	-0.228072
	0111110010_1110001010	// W0076_2048 = +0.972940	-0.231058
	0111110010_1110001000	// W0077_2048 = +0.972226	-0.234042
	0111110001_1110000111	// W0078_2048 = +0.971504	-0.237024
	0111110001_1110000101	// W0079_2048 = +0.970772	-0.240003
25	0111110001_1110000100	// W0080_2048 = +0.970031	-0.242980
	0111110000_1110000010	// W0081_2048 = +0.969281	-0.245955
	0111110000_1110000001	// W0082_2048 = +0.968522	-0.248928
	0111101111_1101111111	// W0083_2048 = +0.967754	-0.251898
	0111101111_1101111110	// W0084_2048 = +0.966976	-0.254866
30	0111101111_1101111100	// W0085_2048 = +0.966190	-0.257831
	0111101110_1101111010	// W0086_2048 = +0.965394	-0.260794
	0111101110_1101111001	// W0087_2048 = +0.964590	-0.263755
	0111101101_1101110111	// W0088_2048 = +0.963776	-0.266713
	0111101101_1101110110	// W0089_2048 = +0.962953	-0.269668
35	0111101101_1101110100	// W0090_2048 = +0.962121	-0.272621
	0111101100_1101110011	// W0091_2048 = +0.961280	-0.275572
	0111101100_1101110001	// W0092_2048 = +0.960431	-0.278520
	0111101011_1101110000	// W0093_2048 = +0.959572	-0.281465
	0111101011_1101110110	// W0094_2048 = +0.958703	-0.284408
40	0111101010_1101101101	// W0095_2048 = +0.957826	-0.287347
	0111101010_1101101011	// W0096_2048 = +0.956940	-0.290285
	0111101001_1101101010	// W0097_2048 = +0.956045	-0.293219
	0111101001_1101101000	// W0098_2048 = +0.955141	-0.296151
	0111101001_1101100111	// W0099_2048 = +0.954228	-0.299080
45	0111101000_1101100101	// W0100_2048 = +0.953306	-0.302006
	0111101000_1101100100	// W0101_2048 = +0.952375	-0.304929
	0111100111_1101100010	// W0102_2048 = +0.951435	-0.307850
	0111100111_1101100001	// W0103_2048 = +0.950486	-0.310767
	0111100110_1101011111	// W0104_2048 = +0.949528	-0.313682
50	0111100110_1101011110	// W0105_2048 = +0.948561	-0.316593
	0111100101_1101011100	// W0106_2048 = +0.947586	-0.319502
	0111100101_1101011011	// W0107_2048 = +0.946601	-0.322408
	0111100100_1101011001	// W0108_2048 = +0.945607	-0.325310
	0111100100_1101011000	// W0109_2048 = +0.944605	-0.328210
55	0111100011_1101010110	// W0110_2048 = +0.943593	-0.331106
	0111100011_1101010101	// W0111_2048 = +0.942573	-0.334000

	0111111111_0000000000	// W0000_2048 = +1.000000	-0.000000
	0111111111_1111111110	// W0001_2048 = +0.999995	-0.003068
	0111111111_1111111101	// W0002_2048 = +0.999981	-0.006136
	0111111111_11111111011	// W0003_2048 = +0.999958	-0.009204
5	0111111111_11111111010	// W0004_2048 = +0.999925	-0.012272
	0111111111_1111111000	// W0005_2048 = +0.999882	-0.015339
	0111111111_1111110111	// W0006_2048 = +0.999831	-0.018407
	0111111111_1111110101	// W0007_2048 = +0.999769	-0.021474
	0111111111_1111110011	// W0008_2048 = +0.999699	-0.024541
10	0111111111_1111110010	// W0009_2048 = +0.999619	-0.027608
	0111111111_1111110000	// W0010_2048 = +0.999529	-0.030675
	0111111111_1111101111	// W0011_2048 = +0.999431	-0.033741
	0111111111_1111101101	// W0012_2048 = +0.999322	-0.036807
	0111111111_1111101100	// W0013_2048 = +0.999205	-0.039873
15	0111111111_1111101010	// W0014_2048 = +0.999078	-0.042938
	0111111111_1111101000	// W0015_2048 = +0.998941	-0.046003
	0111111111_1111100111	// W0016_2048 = +0.998795	-0.049068
	0111111111_1111100101	// W0017_2048 = +0.998640	-0.052132
	0111111111_1111100100	// W0018_2048 = +0.998476	-0.055195
20	0111111111_1111100010	// W0019_2048 = +0.998302	-0.058258
	0111111111_1111100001	// W0020_2048 = +0.998118	-0.061321
	0111111111_1111011111	// W0021_2048 = +0.997925	-0.064383
	0111111111_1111011101	// W0022_2048 = +0.997723	-0.067444
	0111111111_1111011100	// W0023_2048 = +0.997511	-0.070505
25	0111111111_11110111010	// W0024_2048 = +0.997290	-0.073565
	0111111110_11110111001	// W0025_2048 = +0.997060	-0.076624
	0111111110_1111010111	// W0026_2048 = +0.996820	-0.079682
	0111111110_1111010110	// W0027_2048 = +0.996571	-0.082740
	0111111110_1111010100	// W0028_2048 = +0.996313	-0.085797
30	0111111110_1111010011	// W0029_2048 = +0.996045	-0.088854
	0111111110_1111010001	// W0030_2048 = +0.995767	-0.091909
	0111111110_1111001111	// W0031_2048 = +0.995481	-0.094963
	0111111110_1111001110	// W0032_2048 = +0.995185	-0.098017
	0111111101_1111001100	// W0033_2048 = +0.994879	-0.101070
35	0111111101_1111001011	// W0034_2048 = +0.994565	-0.104122
	0111111101_1111001001	// W0035_2048 = +0.994240	-0.107172
	0111111101_1111001000	// W0036_2048 = +0.993907	-0.110222
	0111111101_1111000110	// W0037_2048 = +0.993564	-0.113271
	0111111101_1111000100	// W0038_2048 = +0.993212	-0.116319
40	0111111100_1111000011	// W0039_2048 = +0.992850	-0.119365
	0111111100_1111000001	// W0040_2048 = +0.992480	-0.122411
	0111111100_1111000000	// W0041_2048 = +0.992099	-0.125455
	0111111100_1110111110	// W0042_2048 = +0.991710	-0.128498
	0111111100_1110111101	// W0043_2048 = +0.991311	-0.131540
45	01111111011_1110111011	// W0044_2048 = +0.990903	-0.134581
	01111111011_1110111010	// W0045_2048 = +0.990485	-0.137620
	01111111011_1110111000	// W0046_2048 = +0.990058	-0.140658
	01111111011_1110111010	// W0047_2048 = +0.989622	-0.143695
	01111111010_1110110101	// W0048_2048 = +0.989177	-0.146730
50	01111111010_1110110011	// W0049_2048 = +0.988722	-0.149765
	01111111010_1110110010	// W0050_2048 = +0.988258	-0.152797
	01111111010_1110110000	// W0051_2048 = +0.987784	-0.155828
	01111111001_1110101111	// W0052_2048 = +0.987301	-0.158858
	01111111001_1110101101	// W0053_2048 = +0.986809	-0.161886
55	01111111001_1110101100	// W0054_2048 = +0.986308	-0.164913
	0111111001_1110101010	// W0055_2048 = +0.985798	-0.167938

```

fft_window      #(wordlength,
                 r_wordlength,
                 AddressSize,
                 FIFO_L,
 5             FIFO_L_bits,
                 FIFO_N,
                 FIFO_n,
                 FIFO_A,
                 FIFO_A_bits,
 10            lu_AddressSize,
                 delta,
                 acquired_symbols,
                 pos_threshold,
                 t_offset_threshold,
 15            w_advance,
                 sincint_latency,
                 iqdemod_latency)
window (.in_xr(i_data),
 20           .in_xi(q_data),
                 .clk(clk),
                 .nrst(nrst),
                 .valid_in(valid_in),
                 .valid_out(valid_win_2_fft),
                 .in_resync(in_resync),
 25            .out_iqli(out_iqli),
                 .out_sincqi(out_sincqi),
                 .out_rx_guard(out_rx_guard),
                 .out_acquired(out_acquired),
                 .out_fft_window(out_fft_window),
 30            .enable_3_4(enable_3),
                 .out_test(out_test),
                 .track_ram_address(track_addr),
                 .xri_tmp1(track_data_in),
                 .xri_tmp5(track_data_out),
 35            .track_ram_rnotw(track_rnw),
                 .track_ram_enable(track_ram_enable),
                 .ram_addr(ram_addr),
                 .ram_enable(ram_enable),
                 .ram_rnotw(ram_rnotw),
 40            .ram10_in(ram10_in), // To 1K x 24 bit RAM.
                 .ram10_out(ram10_out), // From 1K x 24 bit RAM.
                 .x1r_10(x1r_10), // To FFT datapath (I).
                 .x1i_10(x1i_10), // To FFT datapath (Q).
                 .z2r_10(z2r_10), // From FFT datapath (I)
 45            .z2i_10(z2i_10), // From FFT datapath (Q)
                 .fft_ram_rnotw(ram_rnotw_fft_2_win),
                 .fft_ram_enable(ram_enable_fft_2_win),
                 .fft_ram_addr(ram_addr_fft_2_win));
endmodule
50

```

## Listing 16

```

// 2048 point FFT twiddle factor coefficients (Radix 4+2).
// Coefficients stored as non-fractional 10 bit integers (scale 1).
55    // Real Coefficient (cosine value) is coefficient high-byte.
    // Imaginary Coefficient (sine value) is coefficient low-byte.

```

```

    .valid_in(valid_win_2_fft),// Input valid.
    .out_xr(i_out), // FFT output data, I.
    .out_xi(q_out), // FFT output data, Q.
    .out_ovf(out_ovf), // Overflow flag.
5     .enable_0(enable_0),
    .enable_1(enable_1),
    .enable_2(enable_2),
    .enable_3(ram_rnotw_fft_2_win),
    .valid_out(valid_out),
10    .ram_address(ram_addr_fft_2_win),
    .ram_enable(ram_enable_fft_2_win),
    .address_rom3(rom3_addr),
    .address_rom4(rom4_addr),

15    // RAM input ports.
    .z2r_4(ram4_in[wordlength-1:0]),
    .z2i_4(ram4_in[wordlength*2-1:wordlength]),
    .z2r_5(ram5_in[wordlength-1:0]),
    .z2i_5(ram5_in[wordlength*2-1:wordlength]),
20    .z2r_6(ram6_in[wordlength-1:0]),
    .z2i_6(ram6_in[wordlength*2-1:wordlength]),
    .z2r_7(ram7_in[wordlength-1:0]),
    .z2i_7(ram7_in[wordlength*2-1:wordlength]),
    .z2r_8(ram8_in[wordlength-1:0]),
    .z2i_8(ram8_in[wordlength*2-1:wordlength]),
25    .z2r_9(ram9_in[wordlength-1:0]),
    .z2i_9(ram9_in[wordlength*2-1:wordlength]),
    .z2r_10(z2r_10),// Frm FFT datapath to window (I).
    .z2i_10(z2i_10),// Frm FFT datapath to window (Q).

30    // RAM output ports.
    .x1r_4(ram4_out[wordlength-1:0]),
    .x1i_4(ram4_out[wordlength*2-1:wordlength]),
    .x1r_5(ram5_out[wordlength-1:0]),
    .x1i_5(ram5_out[wordlength*2-1:wordlength]),
35    .x1r_6(ram6_out[wordlength-1:0]),
    .x1i_6(ram6_out[wordlength*2-1:wordlength]),
    .x1r_7(ram7_out[wordlength-1:0]),
    .x1i_7(ram7_out[wordlength*2-1:wordlength]),
    .x1r_8(ram8_out[wordlength-1:0]),
    .x1i_8(ram8_out[wordlength*2-1:wordlength]),
40    .x1r_9(ram9_out[wordlength-1:0]),
    .x1i_9(ram9_out[wordlength*2-1:wordlength]),
    .x1r_10(x1r_10),// To FFT datapath frm window (I).
    .x1i_10(x1i_10),// To FFT datapath frm window (Q).

45    // ROM output ports.
    .br_3(rom3_data[c_wordlength*2-1:c_wordlength]),
    .bi_3(rom3_data[c_wordlength-1:0]),
    .br_4(rom4_data[c_wordlength*2-1:c_wordlength]),
50    .bi_4(rom4_data[c_wordlength-1:0]));

55    // -----
    // Instance FFT window processor.
    // -----

```

```
wire [AddressSize-1:0] ram_addr,           // RAM address bus.  
      ram_addr_fft_2_win;  
  
5   wire      clk,  
     nrst,  
     in_2k8k,  
     in_resync,  
     valid_in,  
     out_ovf,  
10  enable_0,  
    enable_1,  
    enable_2,  
    enable_3,  
    valid_out,  
15  ram_enable,      // RAM enable signal.  
    ram_rnotw,  
    valid_win_2_fft,  
    ram_rnotw_fft_2_win,  
    ram_enable_fft_2_win,  
20  track_rnw,  
    track_ram_enable,  
    out_iqgi,  
    out_sincgi;  
  
25  wire [wordlength-1:0] x1r_10, x1i_10,  
      z2r_10, z2i_10;  
  
    wire [wordlength-3:0] track_data_in,  
      track_data_out;  
30  wire [FIFO_L_bits-1:0] track_addr;  
  
    wire [1:0]      out_rx_guard;    // Determined guard.  
  
35  wire [c_wordlength*2-1:0] rom3_data,  
      rom4_data;  
  
    wire [rom_AddressSize-6:0] rom3_addr;  
    wire [rom_AddressSize-4:0] rom4_addr;  
40  wire [14:0]      out_test;  
  
    // -----  
    // Instance FFT processor.  
45  // -----  
  
50  fft_r22sdf #(wordlength,  
      c_wordlength,  
      AddressSize,  
      rom_AddressSize,  
      mult_scale)  
    fft (.in_xr(i_data),    // FFT input data, I.  
          .in_xi(q_data),    // FFT input data, Q  
          .clk(clk),        // Master clock.  
          .nrst(nrst),      // Power-up reset.  
          .in_2k8k(in_2k8k), // 2K active low.
```

```

output [wordlength-3:0] track_data_in;

output [wordlength*2-1:0] ram4_in,      // Couple the I/Q data
    ram5_in,      // outputs of each BF
    ram6_in,      // processor to their
    ram7_in,      // respective memory
    ram8_in,      // inputs.
    ram9_in,
    ram10_in;
5

10   output [AddressSize-1:0] ram_addr;      // RAM address bus.

15   output      out_ovf,      // Overflow flag.
        enable_0,      // Enable clock 0.
        enable_1,      // Enable clock 1.
        enable_2,      // Enable clock 2.
        enable_3,      // Enable clock 3.
        valid_out,      // Output data valid.
        ram_enable,      // RAM enable.
20
        ram_rnotw,
        track_rnw,
        track_ram_enable,
        out_iqgi,
        out_sincgi;
25

30   output [FIFO_L_bits-1:0] track_addr;
        output [wordlength-1:0] i_out,      // FFT output data, I.
            q_out;      // FFT output data, Q.

35   wire [9:0]      i_data,      // FFT/WIN input I.
        q_data;      // FFT/WIN output Q.

40   wire [wordlength-1:0] i_out,      // FFT output data, I.
        q_out;      // FFT output data, Q.

45   wire [wordlength*2-1:0] ram4_in,
        ram5_in,
        ram6_in,
        ram7_in,
        ram8_in,
        ram9_in,
        ram10_in;
50

55   wire [wordlength*2-1:0] ram4_out,
        ram5_out,
        ram6_out,
        ram7_out,
        ram8_out,
        ram9_out,
        ram10_out;

```

```

parameter wordlength = 12; // Data wordlength.
parameter c_wordlength = 10; // Coeff wordlength.
parameter AddressSize = 13; // Size of address bus.
parameter rom_AddressSize = 13; // ROM address bus size.
5   parameter mult_scale = 3; // Multiplier scaling:
      // 1 = /4096, 2 = /2048,
      // 3 = /1024, 4 = /512.
parameter r_wordlength = 10; // ROM data wordlength.
10  parameter FIFO_L = 256; // Tracking FIFO length.
parameter FIFO_L_bits = 8; // Track FIFO addr bits
parameter FIFO_N = 64; // Acc length S(i-j).
parameter FIFO_n = 64; // Acc length S(i-n-j).
parameter FIFO_A = 32; // t_offset delay FIFO.
15  parameter FIFO_A_bits = 5; // Track FIFO bits.
parameter lu_AddressSize = 15; // log rom address size.
parameter delta = 20; // Gu threshold distance
parameter acquired_symbols = 2; // Acq symbols before trk
parameter pos_threshold = 3; // for info only.
20  parameter t_offset_threshold = 10; // t_offset valid thresh
parameter w_advance = 10; // win trig frm boundary
parameter sincint_latency = 2; // Latency to sinc intep
parameter iqdemod_latency = 168; // Latency to IQ demod.

// -----
25  // Input/Output ports.
// -----
input clk,          // Master clock.
      nrst,        // Power-up reset.
30  in_2k8k,        // 2K mode active low.
      valid_in,     // Input data valid.
      in_resync;
input [9:0] i_data, // FFT input data, I.
      q_data;      // FFT input data, Q.

input [wordlength-3:0] track_data_out;

40  input [wordlength*2-1:0] ram4_out, // Couple the I/Q data
      ram5_out,    // outputs from the
      ram6_out,    // memory to the
      ram7_out,    // respective butterfly
      ram8_out,    // processors.
      ram9_out,
      ram10_out;

45  input [c_wordlength*2-1:0] rom3_data,
      rom4_data;

50  output [rom_AddressSize-6:0] rom3_addr;
      output [rom_AddressSize-4:0] rom4_addr;

      output [14:0] out_test; // Temp testpin output.

55  output [1:0] out_rx_guard; // Acquired gu length.

```

Notes :

```
*****
5 `timescale 1ns / 100ps

module fft_top      (i_data,
10          q_data,
          clk,
          nrst,
          in_resync,
          in_2k8k,
          valid_in,
15          ram4_in,
          ram5_in,
          ram6_in,
          ram7_in,
          ram8_in,
20          ram9_in,
          ram10_in,
          i_out,
          q_out,
          out_ovf,
25          enable_0,
          enable_1,
          enable_2,
          enable_3,
          valid_out,
30          ram4_out,
          ram5_out,
          ram6_out,
          ram7_out,
          ram8_out,
35          ram9_out,
          ram10_out,
          ram_addr,
          ram_enable,
          ram_rnotw,
40          rom3_addr,
          rom4_addr,
          rom3_data,
          rom4_data,
          track_addr,
45          track_data_in,
          track_data_out,
          track_rnw,
          track_ram_enable,
          out_rx_guard,
50          out_iqgi,
          out_sincgi,
          out_test);

55 // -----
//      Parameter definitions.
// -----
```

```

        t_offset_diff < (1 << 14)) //CORRECT TO DETECT vid = 1 not 0
    )
t_offset_valid <= 0;
else
5   t_offset_valid <= 1;

assign t_offset_thresh = (t_offset_valid) ? t_offset_diff : 0;

// Setup FIFO to perform moving summation of t_offset values.
10  fft_sr_addr #(15, FIFO_A) sr_A (clk, t_offset_ctl,
           t_offset_thresh, // Input.
           t_offset_dly); // Output.

// Compute the moving summation i.e t_offset(i-1) + t_offset(i-2) + ...
15  // We must NOT truncate or round acc as the error will grow across a symbol.
always @(posedge clk)
if (in_resync || !nrst)          // Clear accumulator at
  t_offset_avg <= 0;            // power-up or Resync.
else if (t_offset_ctl)          // Wait until t_offset valid.
20  // Subtract as well as add when averager is full.
  t_offset_avg <= t_offset_avg + t_offset_thresh
  - ((fifo_a_add_sub) ? t_offset_dly : 0);

assign t_offset_scaled =
25  {{(FIFO_A_bits){t_offset_avg[14]}},t_offset_avg[14:FIFO_A_bits]};

// -----
// Code to determine conditions for advancing/retarding tracking window.
// -----
30  assign read_pos = t_offset_scaled;      // +ve (late) so
     // delay read

35  assign read_neg = 2047 + guard_length + 1 - // -ve (early) so
     (~t_offset_scaled + 1); // advance read

40  assign write_pos = guard_length + 1 +
     t_offset_scaled; // delay write
     // +ve (late) so

45  endmodule

```

Listing 15

```

// SccsId: %W% %G%
50  ****
     Copyright (c) 1997 Pioneer Digital Design Centre Limited
Author : Dawood Alam.
55  Description: Verilog code for a structural netlist coupling the Fast Fourier
     Transform (FFT) processor to the window acquisition hardware.

```

```

if (guard_active < (2176+delta)&&      // Test for 2048+128
   guard_active > (2176-delta))      // pt guard length.
begin
  out_rx_guard <= 2'b01;
  guard_length <= 128;
end

5      if (guard_active < (2112+delta)&&      // Test for 2048+64
   guard_active > (2112-delta))      // pt guard length.
begin
  out_rx_guard <= 2'b00;
  guard_length <= 64;
end

10     // Now two peaks per block situation (small guards)
if (guard_active < (5120+delta)&&      // Test for 4096+512+512
   guard_active > (5120-delta))      // 512 pt guard length.
begin
  out_rx_guard <= 2'b11;
20      guard_length <= 512;
end

if (guard_active < (4608+delta)&&      // Test for 4096+256+256
   guard_active > (4608-delta))      // 256 pt guard length.
25      begin
  out_rx_guard <= 2'b10;
  guard_length <= 256;
end

30      if (guard_active < (4352+delta)&&      // Test for 4096+128+128
   guard_active > (4352-delta))      // 128 pt guard length.
begin
  out_rx_guard <= 2'b01;
  guard_length <= 128;
35      end

if (guard_active < (4224+delta)&&      // Test for 4096+64+64
   guard_active > (4224-delta))      // 64 pt guard length.
begin
40      out_rx_guard <= 2'b00;
  guard_length <= 64;
end
end

45      // -----
//       Averager for t_offset in tracking mode.
// -----

50      assign t_offset_diff = t_offset - (2*FIFO_N + FIFO_n); //dly 2 for latency?

always @(posedge clk)
if (in_resync || !nrst) //NEED TO ENABLE THIS!!!!!!
  t_offset_valid <= 0;
else if ((t_offset_diff < (1 << 14 + 1) - t_offset_threshold && // Neg
55      t_offset_diff > (1 << 14 - 1)) ||
  (t_offset_diff > t_offset_threshold &&           // Pos

```

```

    if (read)          // Read if 'read'
    begin            // flag is set.
        if (read_address == FIFO_L-1) // Stop read at
            begin      // end of FIFO.
                read_address <= 0;
                read <= 1'b0;           // Clr read flag.
            end
        else
            read_address <= read_address + 1'b1; // Inc r address.
    10   end

    if (track_mode && t_count == guard_length+1) // Write if the
        write <= 1'b1;             // read is guard
        // depth into FIFO
    15   if (write)
        begin
            if (write_address == FIFO_L-1) // Stop write at
                begin      // end of FIFO.
                    write_address <= 0;
                    write <= 1'b0;
                end
            else
                write_address <= write_address + 1'b1; // Inc w address.
        end
    20   end
    end

    always @ (enable_1_4 or enable_3_4 or read or write or // Assign read and
              read_address or write_address) // write addresses
    30   if (enable_3_4 && read)           // onto common
        track_ram_address = read_address; // address bus
    else if (enable_1_4 && write)         // for tracking
        track_ram_address = write_address; // tsyncram RAM.

    35   // -----
    // Thresholding function to determine precise guard interval.
    // -----
    always @(posedge clk)
    40   if (enable_3_4 && guard_valid)
        begin
            // First, one peak per block situation (large guards)
            if (guard_active < (2560+delta)&& // Test for 2048+512
                guard_active > (2560-delta)) // pt guard length.
        45   begin
            out_rx_guard <= 2'b11;
            guard_length <= 512;
        end

    50   if (guard_active < (2304+delta)&& // Test for 2048+256
          guard_active > (2304-delta)) // pt guard length.
        begin
            out_rx_guard <= 2'b10;
            guard_length <= 256;
        end
    55

```

```

if (in_resync || !nrst)          // Synchronous reset.
    out_sincgi <= 0;
else if (enable_3_4 && tracking &&
         t_count == 15'd0 - sincint_latency) // sincgi guard start.
    5      out_sincgi <= 1'b1;
else if (enable_3_4 && tracking && // TO COMPLETE LATENCY STUFF
         t_count == sincint_latency) // sincgi guard stop.
    out_sincgi <= 1'b0;

10     always @(posedge clk)           // Count over active
        if (in_resync || !nrst)       // interval to generate
            enable_fft <= 1'b0;      // FFT valid pulse.
        else if (enable_3_4 && tracking &&
                  t_count == guard_length + FIFO_L/2 - w_advance) // FFT start point is
15      enable_fft <= 1'b1;          // in middle of write
        else if (enable_3_4 && tracking && // into FIFO_L + advced.
                  fft_valid_count == 2047) // FFT stop after 2048
            enable_fft <= 1'b0;      // samples.

20     always @(posedge clk)
        if (in_resync || !nrst)          // Synchronous reset.
            fft_valid_count <= 0;
        else if (enable_3_4 && tracking && ~enable_fft) // Valid count = 0.
            fft_valid_count <= 0;          // until fft is enabled.
25     else if (enable_3_4 && tracking && enable_fft)
            fft_valid_count <= fft_valid_count + 1'b1; // Count when enabled.

assign valid_out = enable_fft & valid_in; //MUST SYNCHROS Vld every 3 clks?

30     // -----
//      Synchronous RAM address generators.
// -----
35     always @(posedge clk)           // Acqstion FIFO address gen.
        if (!nrst || in_resync)        // Synchronous reset.
            window_ram_addr <= 0;      // Address gen for acq mode.
        else if (enable_2_8)
            window_ram_addr <= window_ram_addr + 1'b1;

40     assign ram_enable_8 = enable_2_8 || enable_3_8 ||
            enable_4_8 || enable_5_8;

always @(posedge clk)           // Tracking FIFO address gen.
begin
45     if (!nrst || in_resync)
        begin
            read_address <= 0;        // Reset track FIFO read addr.
            write_address <= 0;        // Reset track FIFO write addr
            write <= 1'b0;             // Track FIFO, write disabled.
50     read <= 1'b0;                // Track FIFO, read disabled.
        end
    else if (enable_3_4)
        begin
            if (track_mode && t_count == 0) // Track FIFO read
55     read <= 1'b1;                // trigger point.

```

```

dpctl_reset <= 1'b0;      // dp ctl out of reset.
if (read && f_ratio_valid) // Peak detect on rd&vld
begin
  if (f_ratio > max_peak &&
      f_ratio < (1 << r_wordlength)) // Is new peak larger?
  begin
    max_peak <= f_ratio; // If so assign max_peak
    t_offset <= t_count; // Store peak offset.
    end
  10   if (read_address == FIFO_L-1) // If at end of FIFO_L
  begin // move to next state.
    state <= track2; // (read_Addr >> FIFO_L)
    max_peak <= 1'b0; // Reset max peak value.
    end
  15   end
  else
    state <= track1; // else wait in track1.
  end

20   /*S5*/ track2: begin
    if (read && f_ratio_valid) // Peak detect on rd&vld
    begin
      if (f_ratio > max_peak &&
          f_ratio < (1 << r_wordlength)) // Is new peak larger?
      begin
        max_peak <= f_ratio; // If so assign max_peak
        t_offset <= t_count; // Store peak offset
        end
      25   if (read_address == FIFO_L-1) // At end of FIFO_L
      begin // move to next state.
        state <= track1; // (read_Addr >> FIFO_L)
        max_peak <= 1'b0; // Reset max peak value.
        end
      end
      else
        state <= track2; // Wait in this state.
    end

35   default: state <= 3'bXXX;
40   endcase

// -----
// FFT window output decode logic.
// -----
```

45 always @(posedge clk)

50 if (in\_resync || !nrst) // Synchronous reset.

55 out\_iqgi <= 0;

else if (enable\_3\_4 && tracking &&

55 t\_count == 15'd0 - iqdemod\_latency) // iqgi guard start.

out\_iqgi <= 1'b1;

else if (enable\_3\_4 && tracking &&

55 t\_count == iqdemod\_latency) // iqgi guard stop.

out\_iqgi <= 1'b0;

55 always @(posedge clk)

```

        t_retime_acq <= 1'b1;
        end
    else           // Acquisition failed so
        begin       // jump to start and
            state <= start;      // increment the retry
            retry <= retry + 1'b1; // counter.
            t_reset <= 1'b1;     // Reset t_count.
            g_a_reset <= 1'b1;   // Reset g_a_count.
            max_peak <= 1'b0;   // Reset maximum peak.
        end
    end

/*S3*/  peak3: begin
    t_retime_acq <= 1'b0;
    g_a_reset <= 1'b0;      // Next block start cnt
    if (g_a_count < 2048+512) // Search for pos peak2
        begin
        if (f_ratio > max_peak &&
            f_ratio < (1 << r_wordlength)) // Is new peak larger?
            begin
                max_peak <= f_ratio; // If so assign max_peak
                guard_active <= t_count; // Assign guard_active.
            end
        end           // third block complete
    else if// First, one peak per block situation (large guards)
        (guard_active < (2048+guard_length // Peak test 2048
            +delta)&& // + guard length.
        guard_active > (2048+guard_length
            -delta))||

    // Now two peaks per block situation (small guards)
    (guard_active < (4096+(2*guard_length)// Peak 4096 + 2
        +delta)&& // *guard length.
    guard_active > (4096+(2*guard_length
        -delta)))
begin
    acq_symbols <= acq_symbols+1'b1;// Another sym acqurd
    g_a_reset <= 1'b1; // Reset g_a_count.
    max_peak <= 1'b0; // Reset maximum peak.
    t_retime_trk <= 1'b1; // Retime t_count to trk
    track_mode <= 1'b1; // Enter track mode.
    dpctl_reset <= 1'b1; // Reset datapath count
    state <= track1; // Enter track1 state.
end
else           // Acquisition failed so
begin       // jump to start and
state <= start;      // increment the retry
retry <= retry + 1'b1; // counter.
t_reset <= 1'b1;     // Reset t_count.
g_a_reset <= 1'b1;   // Reset g_a_count.
max_peak <= 1'b0;   // Reset maximum peak.
end
end

/*S4*/ track1: begin
    t_retime_trk <= 1'b0; // t_count out retime.

```

```

f_ratio < (1 << r_wordlength)) // Is new peak larger?
begin
max_peak <= f_ratio; // If so assign max_peak
t_reset <= 1; // Reset timing counter.
5      end
end
else           // First block complete.
begin
t_reset <= 1'b0; // t_count out of reset.
10      g_a_reset <= 1'b1; // Reset g_a_count.
max_peak <= 1'b0; // Reset max peak value.
state <= peak2; // Next block search.
end
end
15      /*S2*/ peak2: begin
g_a_reset <= 1'b0; // Next block start cnt
if(g_a_count < 2048+512) // Search for pos peak2
begin
20      if(f_ratio > max_peak &&
f_ratio < (1 << r_wordlength)) // Is new peak larger?
begin
max_peak <= f_ratio; // If so assign max_peak
guard_active <= t_count; // Assign guard_active.
25      end
end           // Second block complete
else if// First, one peak per block situation (large guards)
(guard_active < (2560+delta)&& // Test for 2048+512
guard_active > (2560-delta)))|| // pt guard length.
30      (guard_active < (2304+delta)&& // Test for 2048+256
guard_active > (2304-delta)))|| // pt guard length.

35      (guard_active < (2176+delta)&& // Test for 2048+128
guard_active > (2176-delta)))|| // pt guard length.

40      (guard_active < (2112+delta)&& // Test for 2048+64
guard_active > (2112-delta)))|| // pt guard length.

45      // Now two peaks per block situation (small guards)
(guard_active < (5120+delta)&& // Test 4096+512+512
guard_active > (5120-delta)))|| // pt guard length.

50      (guard_active < (4608+delta)&& // Test 4096+256+256
guard_active > (4608-delta)))|| // pt guard length.

55      (guard_active < (4352+delta)&& // Test 4096+128+128
guard_active > (4352-delta)))|| // pt guard length.

begin
state <= peak3; // Next peak search.
g_a_reset <= 1'b1; // Reset g_a_count.
max_peak <= 1'b0; // Reset maximum peak.
guard_valid <= 1'b1;

```

```

fifo_a_count <= fifo_a_count + 1'b1; // and t_offset is valid.

always @(posedge clk) // Create pulse on entering
if (enable_3_4) // track 4 or track 5 to clk
5 begin // t_offset_ctl once per state
    if ((state == track1 && // transition. We need to
        old_state != track1) || // clock the averager only
        (state == track2 && // once on entering state 4 or
        old_state != track2)) // state 5 hence t_offset_ctl
10 pulse <= 1'b1; // is gated with pulse.
    else
        pulse <= 1'b0;
    old_state <= state;
end
15

always @(posedge clk)
if (in_resync || !nrst)
    tracking <= 1'b0; // Read from 2K/8K FIFO first.
else if (enable_3_4 && track_mode
20     && dp_count == FIFO_L+1) // Check if FIFO_L full in trk
    tracking <= 1'b1; // then read tracking FIFO_L.

// -----
// FFT window timing and sync acquisition/tracking FSM
25 // -----
// Acquisition mode FSM.
if (in_resync || !nrst) // Synchronous power-up reset.
begin
30     state <= start; // FSM starts in resync.
     track_mode <= 1'b0; // Start in acquisition mode.
     t_reset <= 1'b0; // Reset main timing counter.
     dpctl_reset <= 1'b0; // dp_ctl out of reset.
35     g_a_reset <= 1'b0; // Reset guard_active counter.
     max_peak <= 1'b0; // Reset max peak value.
     retry <= 0; // Reset no of retry's.
     acq_symbols <= 0; // Reset acquired no symbols.
     guard_valid <= 1'b0; // Guard data is valid.
     t_retime_acq <= 1'b0; // Do not retime at resync.
40     t_retime_trk <= 1'b0; // Do not retime at resync.
end
else if (enable_3_4)
    case (state)
/*S0*/    start: begin
45        g_a_reset <= 1'b0; // g_a_reset out of rst
        t_reset <= 1'b0; // t_count out of reset.
        guard_valid <= 1'b0; // Guard invalid.
        // MUST ACT ON RETRYS TOO!!
        state <= peak1; // Enter peak1 state.
50    end
/*S1*/    peak1: begin
        t_reset <= 1'b0; // t_count out of reset.
        if (g_a_count < 2048+512) // Search for pos peak1
55            begin
                if (f_ratio > max_peak &&

```

```

fifo_a_add_sub <= 0;
else if (enable_3_4 && fifo_a_count == FIFO_A) // fifo_a is full
  fifo_a_add_sub <= 1; // so add and sub.

5   always @(posedge clk)
    if (in_resync || !nrst) // Synchronous reset.
      t_offset_avg_valid <= 1'b0; // Average value is
    else if (enable_3_4 && fifo_a_count == FIFO_A + 1) // valid one cycle
      t_offset_avg_valid <= 1'b1; // after add_sub sig.

10  assign dp_control = enable_3_4 && // Datapath enable
      (~track_mode || track_mode && read); // in acq/track mode.

15  assign t_offset_ctl = enable_3_4 && t_offset_valid // clock averager
      && pulse && !read && tracking; // dp control signal.

// -----
// FFT window timing and sync acquisition/tracking timing counters.
// ----

20  always @(posedge clk)
    if (in_resync || !nrst || t_reset) // Synchronous power-up reset.
      t_count <= 0; // Reset main timing counter.
    else if (enable_3_4 && t_retime_acq) // Retime to count from last
      t_count <= t_count - guard_active; // peak to current time.
    else if (enable_3_4 && ~track_mode) // Count if not in track mode
      t_count <= t_count + 1'b1;
    else if (enable_3_4 && t_retime_trk) // Otherwise must be in track
      t_count <= t_count - guard_active // so advance timing for acq
      + (2*FIFO_N + FIFO_n + 2); // FIFO_L read trig point then
    else if (enable_3_4)
      begin // wrap round t_count at
        if (t_count == 2047+guard_length) // end of guard+active length.
          t_count <= 0; // Needed as a reference to
        else // track peak movement in
          t_count <= t_count + 1'b1; // capture window.
      end

35  always @(posedge clk)
    if (in_resync || !nrst || g_a_reset) // Synchronous power-up reset.
      g_a_count <= 0; // Reset guard_active counter.
    else if (enable_3_4 && f_ratio_valid) // g_a count when f_ratio valid
      g_a_count <= g_a_count + 1'b1; // Guard active timing counter

40  always @(posedge clk) // Datapath timing counter.
    if (in_resync || !nrst || dpctl_reset) // Synchronous reset.
      dp_count <= 0; // Reset datapath control.
    else if (enable_3_4 && ~track_mode) // Always count in acquire
      dp_count <= dp_count + 1'b1; // mode on clk 0.
    else if (enable_3_4 && track_mode && read) // Count when reading data in
      dp_count <= dp_count + 1'b1; // tracking mode.

45  always @(posedge clk)
    if (in_resync || !nrst) // Synchronous reset.
      fifo_a_count <= 0;
    else if (enable_3_4 && t_offset_ctl) // Only clock averager if Trk

```

```

acc <= acc + xri_tmp3 - ((acc_add_sub) ? xri_tmp4 : 0);

assign lu_address = acc; // Ensure lu_address is large enough to
// accomodate acc number range.

5 fft_window_lu #(r_wordlength, lu_AddressSize) // Case table instance
log_lu (clk, dp_control, lu_address, lu_data); // for a log lookup.

10 // Setup 5 bit FIFO to determine the delayed variance.
fft_sr_addr #(r_wordlength, FIFO_n) sr_n (clk, dp_control, // Length=FIFO_n.
lu_data, // Input.
xri_tmp9); // Output.

15 // Determine difference of logs and hence the f_ratio when it is valid.
always @(lu_data or xri_tmp9 or f_ratio_valid)
f_ratio = (f_ratio_valid) ? lu_data - xri_tmp9 : 1'b0;

20 // -----
// Positive threshold (for information only)
// -----
assign pos_peak =((f_ratio >= pos_threshold &&
f_ratio < (1 << r_wordlength)) ? 1'b1 : 1'b0);

25 // -----
// FFT window datapath control registers.
// -----
always @(posedge clk)
30 if (in_resync || !nrst || dpctl_reset) // Synchronous reset.
begin
    f_ratio_valid <= 1'b0; // Initialise datapath
    acc_add <= 1'b0; // control registers.
    acc_add_sub <= 1'b0;
35 end
else if (enable_3_4 && ~read) // Acquisition mode
begin // Use 2K/8K FIFO.
    if (dp_count == 2047 + FIFO_N + FIFO_n + 1 + 1) // f_ratio only valid
        f_ratio_valid <= 1'b1; // after sum of FIFO
40    if (dp_count == 2047) // +acc+ROM latencys
        acc_add <= 1'b1; // Add if acc full.
    if (dp_count == 2047+FIFO_N) // Add/sub when FIFO
        acc_add_sub <= 1'b1; // N is full.
end
45 else if (enable_3_4 && read) // Tracking mode
begin // Use FIFO_L.
    if (dp_count == FIFO_L + FIFO_N + FIFO_n + 1 + 1) // f_ratio only valid
        f_ratio_valid <= 1'b1; // after sum of FIFO
    if (dp_count == FIFO_L) // +acc+ROM latencys
        acc_add <= 1'b1; // Add if acc full.
50    if (dp_count == FIFO_L + FIFO_N) // Add/sub when FIFO
        acc_add_sub <= 1'b1; // N is full.
end

55 always @(posedge clk)
if (in_resync || !nrst) // Synchronous reset.

```

```

begin          // RAM Mux code.
if (!tracking)      // In window acq
begin            // mode.
    msb_out = ram10_out[2*wordlength-1:wordlength];
    lsb_out = ram10_out[wordlength-1:0];      // Connect window
    ram10_in[2*wordlength-1:wordlength] = msb_in; // datapath & RAM
    ram10_in[wordlength-1:0] = lsb_in;        // control signals
    ram_enable = ram_enable_8;
    ram_rnotw = enable_3_8;
    ram_addr = window_ram_addr;
end
else           // In tracking
begin          // mode, therefore
    x1r_10 = ram10_out[2*wordlength-1:wordlength]; // FFT functional.
    x1i_10 = ram10_out[wordlength-1:0];
    ram10_in[2*wordlength-1:wordlength] = z2r_10; // Connect FFT
    ram10_in[wordlength-1:0] = z2i_10;        // datapath & RAM
    ram_enable = fft_ram_enable;        // control signals
    ram_rnotw = fft_ram_rnotw;
    ram_addr = fft_ram_addr;
end
end

assign track_ram_rnotw = enable_3_4 & read;
25 assign track_ram_enable = (enable_3_4 & read) || (enable_1_4 & write);

// Select which FIFO we read data from depending on tracking or acquire mode.
always @(xri_tmp5 or xri_tmp2 or tracking)
if(tracking)
    xri_tmp6 = xri_tmp5;                  // Tracking mode
else
    xri_tmp6 = xri_tmp2;                // Acquisition
                                // mode data.

// Perform computation of s(i-j)
35 always @(xri_tmp1 or xri_tmp6)
    xri_tmp7 = xri_tmp1 - xri_tmp6;

// Take the modulus of xri_tmp7;
40 always @(xri_tmp7)
    if (xri_tmp7[wordlength-2])          // Check MSB for
        xri_tmp3 = -xri_tmp7;          // neg number.
    else
        xri_tmp3 = xri_tmp7;

45 // Setup FIFO to perform moving summation of s(i-j) values.
fft_sr_addr #(wordlength-2, FIFO_N) sr_N (clk, dp_control, // Length=FIFO_N.
                                             xri_tmp3, // Input.
                                             xri_tmp4); // Output.

50 // Compute the moving summation i.e S(i-j) = s(i-1,j-1) + s(i-2,j-2) + ...
// We must NOT truncate or round acc as the error will grow across a symbol.
always @(posedge clk)
if (in_resync || !rst || dpctl_reset) // Clear accumulator at
    acc <= 0;                      // power-up or Resync or trk.
55 else if (dp_control & acc_add)   // Wait until acc data valid.
    // Subtract as well as add when 2K/8K FIFO is full.

```

```

begin
    xr_reg <= in_xr;
    xi_reg <= in_xi;
end
5   else if (enable_3_4)
begin
    xr_reg <= in_xr;
    xi_reg <= in_xi;
end
10  // Take the modulus of in_xr and in_xi and add together (|in_xr| + |in_xi|).
always @(xr_reg or xi_reg)
begin
    if (xr_reg[wordlength-3])    // Checking MSB for negative number.
15    xr_tmp1 = -xr_reg;
else
    xr_tmp1 = xr_reg;

    if (xi_reg[wordlength-3])    // Checking MSB for negative number.
20    xi_tmp1 = -xi_reg;
else
    xi_tmp1 = xi_reg;

    xri_tmp1 = xr_tmp1 + xi_tmp1;
25  end

assign even_symbol = r[2];

always @((even_symbol or msb_out_tmp or ram_in or lsb_out) // Mux MSB/LSB to
30  if (even_symbol)           // allow 1K RAM
begin               // to act as a 2K
    ram_out = lsb_out;        // FIFO, possible
    lsb_in_tmp = ram_in;      // since data
    end                   // bitwidth is 2b
35  else                  // bits wide in
begin               // the 1K RAM and
    ram_out = msb_out_tmp;   // only b bits are
    msb_in = ram_in;         // required in the
    end                   // data path.
40
always @(posedge clk)          // Delay even
begin               // symbols by one
    if (enable_5_8)           // symbol so that
        lsb_in <= lsb_in_tmp; // two symbols are
45  if (enable_7_8)           // written & read
        msb_out_tmp <= msb_out; // to the ram.
    end

assign xri_tmp2 = ram_out;      // Map RAM I/O
50  assign ram_in = xri_tmp1;   // to dp wires.

always @((ram10_out or msb_in or lsb_in or z2r_10 or z2i_10
55  or ram_enable_8 or enable_3_8
        or fft_ram_enable or fft_ram_rnotw
        or window_ram_addr or fft_ram_addr
        or tracking)       // FFTWINDOW FIFO

```

```

wire [wordlength-1:0] ram_in;
reg [wordlength-1:0] lsb_out,
    msb_out;
5   reg [wordlength-1:0] ram_out,
    msb_in,
    lsb_in;
10  wire [wordlength*2-1:0] ram10_out;
    reg [wordlength*2-1:0] ram10_in;

    reg [wordlength-1:0] x1r_10, x1i_10;
    wire [wordlength-1:0] z2r_10, z2i_10;
15  wire [14:0]    out_test;
    wire [14:0]    t_offset_diff,    // Actual +/- difference
                    t_offset_thresh,  // Valid offset (maybe)
                    t_offset_dly,    // Delayed of above.
20   t_offset_scaled, // Scalled to t_offset.
    read_pos,      // read trig, +ve offset
    read_neg,      // read trig, -ve offset
    write_pos,     // write trig, +ve offset
    write_neg;     // write trig, -ve offset
25  assign out_test = t_offset_diff;
// -----
// Fast 40 MHz clock decoder and valid_in control.
// -----
30  always @(posedge clk)
    if (!nrst)           // Synchronous power-up reset.
        r <= 0;
    else if (valid_in)    // Count if input data valid.
35    r <= r + 1'b1;

    assign enable_0_4 = valid_in & (~r[1] & ~r[0]); // Gate valid_in with
    assign enable_1_4 = valid_in & (~r[1] & r[0]); // decoded enable signals
    assign enable_2_4 = valid_in & ( r[1] & ~r[0]); // to control all reg's.
40    assign enable_3_4 = valid_in & ( r[1] & r[0]); // Enables every 4 clk's

    assign enable_1_8 = valid_in & (~r[2] & ~r[1] & r[0]);
    assign enable_2_8 = valid_in & (~r[2] & r[1] & ~r[0]);
    assign enable_3_8 = valid_in & (~r[2] & r[1] & r[0]);
45    assign enable_4_8 = valid_in & ( r[2] & ~r[1] & ~r[0]); // Enables every 8
    assign enable_5_8 = valid_in & ( r[2] & ~r[1] & r[0]); // clk's
    assign enable_6_8 = valid_in & ( r[2] & r[1] & ~r[0]);
    assign enable_7_8 = valid_in & ( r[2] & r[1] & r[0]);
50  // -----
// The entire data path incorporating the FIFO's, ROM and comparators.
// -----
55  // Register the data inputs to the windowing module.
always @(posedge clk)
    if (in_resync || !nrst)

```

```

reg [2:0]      r;          // Clock decode counter.
reg [1:0]      out_rx_guard;    // Determined guard.
reg [r_wordlength:0] f_ratio;    // Statistical F ratio.
reg [10:0]     fft_valid_count; // Counts no of FFT vlds
5   reg [AddressSize-1:0] window_ram_addr, // ram_address counter.
     ram_addr;
reg [14:0]     t_count,      // Window timing count.
     t_offset;      // Peak offset from t_ct
10  reg [14:0]     g_a_count;    // Guard_active counter.
reg [14:0]     dp_count;      // Datapath timing count
reg [14:0]     t_offset_avg;  // Averaged offset.
reg [2:0]      state,        // Acq/Track FSM state.
     old_state;     // Old tracking state.
reg [9:0]      guard_length; // Thresholded guard len
15
reg [FIFO_A_bits:0] fifo_a_count; // Count till fifo_a ful
// 1 bit more -> retime

reg [r_wordlength-1:0] max_peak; // Maximum positive peak
20
reg [wordlength-1:0] msb_out_tmp, // Temporary stores for
     lsb_in_tmp; // even symbols to RAM.
wire [AddressSize-1:0] fft_ram_addr; // From FFT RAM addr gen

25  wire      clk,          // Master clock.
     nrst,          // Power-up reset.
     enable_0_4,    // Clock enable 0 in 4.
     enable_1_4,    // Clock enable 1 in 4.
     enable_2_4,    // Clock enable 2 in 4.
     enable_3_4,    // Clock enable 3 in 4.
     enable_0_8,    // Clock enable 0 in 8.
30   enable_1_8,    // Clock enable 1 in 8.
     enable_2_8,    // Clock enable 2 in 8.
     enable_3_8,    // Clock enable 3 in 8.
     enable_4_8,    // Clock enable 4 in 8.
     enable_5_8,    // Clock enable 5 in 8.
     enable_6_8,    // Clock enable 6 in 8.
     enable_7_8,    // Clock enable 7 in 8.
     ram_enable_8, // Acq FIFO enable.
40   track_ram_enable, // Tracking RAM enable
     track_ram_rnotw, // Tracking RAM rnotw.
     even_symbol,   // valid on even symbols
     in_resync,    // Resync to acqn mode.
     pos_peak,     // +ve peak, ref only!
45   dp_control,   // Datapath acq/trk ctl.
     t_offset_ctl, // Trk averager dp ctl.
     fft_ram_rnotw,
     fft_ram_enable;

50   wire [lu_AddressSize-1:0] lu_address;
wire [r_wordlength-1:0] lu_data,
     xri_tmp9;
wire [wordlength-3:0] xri_tmp2,
     xri_tmp4,
     xri_tmp5,
55   in_q,
     out_q;

```

```

    ram_rnotw;

output [FIFO_L_bits-1:0] track_ram_address; // Tracking ram address
5   output [1:0]      out_rx_guard;      // Acquired gu length.

output [AddressSize-1:0] ram_addr;

output [wordlength-1:0] x1r_10, x1i_10; // To FFT datapath.

10
// -----
//      Wire/register declarations.
// -----


15  reg      out_acquired,      // Symbol acquired flag.
    out_fft_window,      // FFT window signal.
    tracking,           // Tracking mode data.
    acc_add,            // Acc add only flag.
    acc_add_sub,        // Acc add/sub flag.
20   fifo_a_add_sub,        // FIFO_A add/sub flag.
    f_ratio_valid,     // F ratio is valid
    read,              // Track FIFO read flag.
    write,             // Track FIFO write flag
    track_mode,         // Track/Acq status flag
25   dipcti_reset,        // Datapath control rst.
    t_reset,            // Timing counter reset.
    g_a_reset,          // Guard_active cnt rst.
    guard_valid,        // Guard signal is valid
    t_retime_acq,       // Retime timing counter
30   t_retime_trk,        // Retiming for tracking
    t_offset_valid,     // Peak offset valid.
    t_offset_avg_valid, // Average offset valid.
    pulse,              // Pulse on states 4 & 5
    enable_fft,         // FFT enabled flag.
35   out_sincgi,          // Guard int to sincint.
    out_iqli,           // Guard int to iq demod
    ram_enable,
    ram_rnotw;

40  reg [14:0]  guard_active; // Guard+active length.
    reg [3:0]    retry;      // No failed retry's.
    acq_symbols; // No of acquired symbols
    reg [wordlength-2:0] xri_tmp7; // Delayed difference.
    reg [wordlength-3:0] xr_reg, // (10 bits)
45   xi_reg,
        xri_tmp1,      // Sum of |I| + |Q|.
        xri_tmp3,      // Delayed |difference|.
        xri_tmp6;      // FIFO 2K/L output.

50  reg [FIFO_L_bits-1:0] read_address, // Track FIFO read addr.
    write_address, // Track FIFO write adr.
    track_ram_address; // Tracking ram address;

55  reg [lu_AddressSize-1:0] acc; // Holds input variance.
    reg [wordlength-4:0] xr_tmp1, // |I|.
        xi_tmp1; // |Q|.

```

```

parameter      FIFO_N = 64;      // Acc length S(i-j).
parameter      FIFO_n = 64;      // Acc length S(i-n-j).
parameter      FIFO_A = 32;      // t_offset dly FIFO+1.
parameter      FIFO_A_bits = 5;   // Track FIFO bits.
5            parameter      lu_AddressSize = 15; // log lu address size.
parameter      delta = 20;       // Gu threshold distance
parameter      acquired_symbols = 2; // Acq symbols before trk
parameter      pos_threshold = 3; // For info only.
10           parameter      t_offset_threshold = 10; // t_offset valid thresh
parameter      w_advance = 10;    // win trig frm boundary
parameter      sincint_latency = 2; // Latency to sinc intep
parameter      iqdemod_latency = 168; // Latency to IQ demod.

15           parameter      start = 3'b000, // Search for neg peak.
               peak1 = 3'b001, // 1st pos peak found.
               peak2 = 3'b010, // 2nd pos peak found.
               peak3 = 3'b011, // 3rd pos peak found.
               track1 = 3'b100, // Tracking mode1.
               track2 = 3'b101; // Tracking mode1.

20           // -----
21           // Input/Output ports.
22           // -----
23
25           input      clk,        // Master clock.
               nrst,       // Power-up reset.
               valid_in,   // Input data valid.
               in_resync,  // Sync FSM into Acqure.
               fft_ram_rnotw,
30           fft_ram_enable;

               input [AddressSize-1:0] fft_ram_addr;
               input [wordlength-3:0] in_xr,      // FFT input data, I.
35           in_xi,       // FFT input data, Q.
               xri_tmp5;   // Track RAM output.

               input [wordlength*2-1:0] ram10_out; // From 1K x 24 bit RAM.

40           input [wordlength-1:0] z2r_10, z2i_10; // From FFT datapath.

               output [wordlength*2-1:0] ram10_in; // To 1K x 24 bit RAM.

               output [wordlength-3:0] xri_tmp1; // Track RAM input.

45           output [14:0]     out_test;    // Temp testpin output.

               output      out_iqli,    // I/Q demod guard info.
               out_sincgi,  // Sinc int. guard info.
               out_acquired, // Symbol acquired flag.
               out_fft_window, // FFT processor st/stp
               enable_3_4,
               valid_out,
               track_ram_rnotw,
               track_ram_enable,
50           ram_enable,
55           ram_enable,

```

of valid\_in and provides the necessary signals for the I/Q demodulator, sync interpolator and error handler.

To DO: Check between successive symbol acquires for consistency  
5 in timing.

Window timing pulse  
tracking mode, filter peaks  
IQ and sync interpolator guard pulses.  
Override functions for timing.

10 Gain confidence by comparing symbol\_acq vs retries

---

'timescale 1ns / 100ps

```
15 module fft_window (in_xr,
    in_xi,
    clk,
    nrst,
20    valid_in,
    valid_out,
    in_resync,
    out_iqli,
    out_sincgi,
25    out_rx_guard,
    out_acquired,
    out_fft_window,
    enable_3_4,
    out_test,
30    track_ram_address,
    xri_tmp1,
    xri_tmp5,
    track_ram_rnotw,
    track_ram_enable,
35    ram_addr,
    ram_enable,
    ram_rnotw,
    ram10_in,
    ram10_out,
40    x1r_10,           // To FFT datapath (I).
    x1i_10,           // To FFT datapath (Q).
    z2r_10,           // From FFT datapath (I)
    z2i_10,           // From FFT datapath (Q)
    fft_ram_rnotw,   // From FFT addr gen.
45    fft_ram_enable, // From FFT addr gen.
    fft_ram_addr);  // From FFT addr gen.
```

---

// -----

// Parameter definitions.

---

```
50 parameter wordlength = 12; // Data wordlength.
parameter r_wordlength = 10; // ROM data wordlength.
parameter AddressSize = 13; // Size of address bus.
55 parameter FIFO_L = 256; // Tracking FIFO length.
parameter FIFO_L_bits = 8; // Track FIFO addr bits
```

```

13'b111011111110z : data_tmp1 = 10'b0111111100;
13'b1110111111110 : data_tmp1 = 10'b0111111100;
13'b1111000zzzzz : data_tmp1 = 10'b0111111100;
13'b1111001000zzz : data_tmp1 = 10'b0111111100;
5   13'b11110010010zz : data_tmp1 = 10'b0111111100;
13'b111100100110z : data_tmp1 = 10'b0111111100;

13'b11110010z11z : data_tmp1 = 10'b0111111101;
13'b1111001z10zzz : data_tmp1 = 10'b0111111101;
10  13'b1111001z110zz : data_tmp1 = 10'b0111111101;
13'b1111001z1110z : data_tmp1 = 10'b0111111101;
13'b111100110zzzz : data_tmp1 = 10'b0111111101;
13'b111100111111z : data_tmp1 = 10'b0111111101;
13'b1111010zzzzz : data_tmp1 = 10'b0111111101;
15  13'b111101100zzzz : data_tmp1 = 10'b0111111101;
13'b1111011010zzz : data_tmp1 = 10'b0111111101;

13'b1111011z11zzz : data_tmp1 = 10'b0111111110;
13'b111101110zzzz : data_tmp1 = 10'b0111111110;
20  13'b1111011110zzz : data_tmp1 = 10'b0111111110;
13'b1111100zzzzz : data_tmp1 = 10'b0111111110;
13'b11111010zzzzz : data_tmp1 = 10'b0111111110;
13'b11111011000zz : data_tmp1 = 10'b0111111110;

25   13'b111110110z1zz : data_tmp1 = 10'b0111111111;
13'b11111011z10zz : data_tmp1 = 10'b0111111111;
13'b11111z1110zzz : data_tmp1 = 10'b0111111111;
13'b11111z11111zz : data_tmp1 = 10'b0111111111;
13'b1111110zzzzz : data_tmp1 = 10'b0111111111;
30   13'b11111110zzzzz : data_tmp1 = 10'b0111111111;
13'b111111110zzzz : data_tmp1 = 10'b0111111111;
13'b11111111110zz : data_tmp1 = 10'b0111111111;
default: data_tmp1 = 10'bxxxxxxxxxx;
endcase
35
always @(posedge clk)
if (enable_3)
  data_tmp2 <= data_tmp1;

40 assign out_data = data_tmp2;

endmodule

```

## Listing 14

45 // SccsId: %W% %G%  
\*\*\*\*\*

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50 Author : Dawood Alam.

Description: Verilog code for windowing algorithm to enable detection of the "active interval" of the COFDM symbol for guard values of:  
64, 128, 256, 512 and an active interval of 2048. (RTL)

55 Notes : This module generates the window signal for the FFT in the form

13'b110110110zzzz : data\_tmp1 = 10'b0111110111;  
13'b11011011110zz : data\_tmp1 = 10'b0111110111;  
13'b1101110zzzzzz : data\_tmp1 = 10'b0111110111;

5   13'b1101111zzzzzz : data\_tmp1 = 10'b0111111000;  
13'b11100000zzzzzz : data\_tmp1 = 10'b0111111000;  
13'b111000010zzzzz : data\_tmp1 = 10'b0111111000;  
13'b1110000110zzz : data\_tmp1 = 10'b0111111000;  
13'b11100001110zz : data\_tmp1 = 10'b0111111000;  
10   13'b111000011110z : data\_tmp1 = 10'b0111111000;

13'b111000z11111z : data\_tmp1 = 10'b0111111001;  
13'b11100010zzzzzz : data\_tmp1 = 10'b0111111001;  
13'b111000110zzzzz : data\_tmp1 = 10'b0111111001;

15   13'b1110001110zzz : data\_tmp1 = 10'b0111111001;  
13'b11100011110zz : data\_tmp1 = 10'b0111111001;  
13'b111000111110z : data\_tmp1 = 10'b0111111001;  
13'b11100100zzzzzz : data\_tmp1 = 10'b0111111001;  
13'b111001010zzzzz : data\_tmp1 = 10'b0111111001;

20   13'b1110010110zzz : data\_tmp1 = 10'b0111111001;  
13'b11100101110zz : data\_tmp1 = 10'b0111111001;  
13'b111001011110z : data\_tmp1 = 10'b0111111001;  
13'b1110010111110 : data\_tmp1 = 10'b0111111001;

25   13'b111001z111111 : data\_tmp1 = 10'b0111111010;  
13'b11100110zzzzzz : data\_tmp1 = 10'b0111111010;  
13'b111001110zzzzz : data\_tmp1 = 10'b0111111010;  
13'b1110011110zzz : data\_tmp1 = 10'b0111111010;  
13'b11100111110zz : data\_tmp1 = 10'b0111111010;

30   13'b111001111110z : data\_tmp1 = 10'b0111111010;  
13'b1110011111110 : data\_tmp1 = 10'b0111111010;  
13'b1110100zzzzzzz : data\_tmp1 = 10'b0111111010;  
13'b111010100000z : data\_tmp1 = 10'b0111111010;

35   13'b1110101000z1z : data\_tmp1 = 10'b0111111011;  
13'b111010100z10z : data\_tmp1 = 10'b0111111011;  
13'b11101010z10zz : data\_tmp1 = 10'b0111111011;  
13'b11101010z111z : data\_tmp1 = 10'b0111111011;  
13'b1110101z10zzz : data\_tmp1 = 10'b0111111011;

40   13'b1110101z1110z : data\_tmp1 = 10'b0111111011;  
13'b111010110zzzzz : data\_tmp1 = 10'b0111111011;  
13'b11101011110zz : data\_tmp1 = 10'b0111111011;  
13'b111010111111z : data\_tmp1 = 10'b0111111011;  
13'b1110110zzzzzzz : data\_tmp1 = 10'b0111111011;

45   13'b11101110000zz : data\_tmp1 = 10'b0111111011;  
13'b111011100010z : data\_tmp1 = 10'b0111111011;  
13'b1110111000110 : data\_tmp1 = 10'b0111111011;

50   13'b111011100z111 : data\_tmp1 = 10'b0111111100;  
13'b11101110z10zz : data\_tmp1 = 10'b0111111100;  
13'b11101110z110z : data\_tmp1 = 10'b0111111100;  
13'b11101110z1110 : data\_tmp1 = 10'b0111111100;  
13'b1110111z10zzz : data\_tmp1 = 10'b0111111100;  
13'b1110111z11111 : data\_tmp1 = 10'b0111111100;

55   13'b111011110zzzz : data\_tmp1 = 10'b0111111100;  
13'b1110111110zz : data\_tmp1 = 10'b0111111100;

13'b1100011111zzz : data\_tmp1 = 10'b0111110010;  
13'b1100100zzzzzz : data\_tmp1 = 10'b0111110010;  
13'b11001010zzzzzz : data\_tmp1 = 10'b0111110010;  
13'b1100101100zzz : data\_tmp1 = 10'b0111110010;  
5 13'b110010110100z : data\_tmp1 = 10'b0111110010;  
  
13'b1100101101z1z : data\_tmp1 = 10'b0111110011;  
13'b11001011z110z : data\_tmp1 = 10'b0111110011;  
13'b1100101110zzz : data\_tmp1 = 10'b0111110011;  
10 13'b11001011110zz : data\_tmp1 = 10'b0111110011;  
13'b11001011111z : data\_tmp1 = 10'b0111110011;  
13'b1100110zzzzzz : data\_tmp1 = 10'b0111110011;  
13'b110011100zzzz : data\_tmp1 = 10'b0111110011;  
13'b1100111010zzz : data\_tmp1 = 10'b0111110011;  
15 13'b11001110110zz : data\_tmp1 = 10'b0111110011;  
13'b1100111011100 : data\_tmp1 = 10'b0111110011;  
  
13'b11001110111z1 : data\_tmp1 = 10'b0111110100;  
13'b1100111z1110 : data\_tmp1 = 10'b0111110100;  
20 13'b110011110zzzz : data\_tmp1 = 10'b0111110100;  
13'b1100111110zzz : data\_tmp1 = 10'b0111110100;  
13'b11001111110zz : data\_tmp1 = 10'b0111110100;  
13'b110011111110z : data\_tmp1 = 10'b0111110100;  
13'b1100111111111 : data\_tmp1 = 10'b0111110100;  
25 13'b1101000zzzzzz : data\_tmp1 = 10'b0111110100;  
13'b110100100zzzz : data\_tmp1 = 10'b0111110100;  
13'b110100101000z : data\_tmp1 = 10'b0111110100;  
13'b1101001010010 : data\_tmp1 = 10'b0111110100;  
  
30 13'b1101001010z11 : data\_tmp1 = 10'b0111110101;  
13'b110100101z10z : data\_tmp1 = 10'b0111110101;  
13'b110100101z110 : data\_tmp1 = 10'b0111110101;  
13'b1101001z110zz : data\_tmp1 = 10'b0111110101;  
13'b1101001z1111 : data\_tmp1 = 10'b0111110101;  
35 13'b110100110zzzz : data\_tmp1 = 10'b0111110101;  
13'b1101001110zzz : data\_tmp1 = 10'b0111110101;  
13'b1101001111110z : data\_tmp1 = 10'b0111110101;  
13'b1101001111110 : data\_tmp1 = 10'b0111110101;  
13'b1101010zzzzzz : data\_tmp1 = 10'b0111110101;  
40 13'b1101011000zzz : data\_tmp1 = 10'b0111110101;  
13'b110101100100z : data\_tmp1 = 10'b0111110101;  
  
13'b1101011001z1z : data\_tmp1 = 10'b0111110110;  
13'b11010110z110z : data\_tmp1 = 10'b0111110110;  
45 13'b1101011z10zzz : data\_tmp1 = 10'b0111110110;  
13'b1101011z110zz : data\_tmp1 = 10'b0111110110;  
13'b1101011z1111z : data\_tmp1 = 10'b0111110110;  
13'b1101011110zzzz : data\_tmp1 = 10'b0111110110;  
13'b110101111110z : data\_tmp1 = 10'b0111110110;  
50 13'b1101100zzzzzz : data\_tmp1 = 10'b0111110110;  
13'b11011010000zz : data\_tmp1 = 10'b0111110110;  
  
13'b110110100z1zz : data\_tmp1 = 10'b0111110111;  
13'b11011010z10zz : data\_tmp1 = 10'b0111110111;  
55 13'b1101101z10zzz : data\_tmp1 = 10'b0111110111;  
13'b1101101z111zz : data\_tmp1 = 10'b0111110111;

13'b1011100zzzzz : data\_tmp1 = 10'b0111101101;  
13'b10111010000zz : data\_tmp1 = 10'b0111101101;  
13'b101110100010z : data\_tmp1 = 10'b0111101101;

5   13'b101110100z11z : data\_tmp1 = 10'b0111101110;  
13'b10111010z10zz : data\_tmp1 = 10'b0111101110;  
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13'b1011101z111z : data\_tmp1 = 10'b0111101110;  
10  13'b101110110zzzz : data\_tmp1 = 10'b0111101110;  
13'b10111011110zz : data\_tmp1 = 10'b0111101110;  
13'b101110111110z : data\_tmp1 = 10'b0111101110;  
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13'b1011110100zzz : data\_tmp1 = 10'b0111101110;

15  13'b10111101010zz : data\_tmp1 = 10'b0111101110;  
13'b101111010110z : data\_tmp1 = 10'b0111101110;  
13'b1011110101110 : data\_tmp1 = 10'b0111101110;

20  13'b10111101z1111 : data\_tmp1 = 10'b0111101111;  
13'b101111z110zzz : data\_tmp1 = 10'b0111101111;  
13'b101111z1110zz : data\_tmp1 = 10'b0111101111;  
13'b101111z11110z : data\_tmp1 = 10'b0111101111;  
13'b101111z111110 : data\_tmp1 = 10'b0111101111;  
25  13'b10111110zzzzz : data\_tmp1 = 10'b0111101111;  
13'b101111110zzzz : data\_tmp1 = 10'b0111101111;  
13'b110000000zzzz : data\_tmp1 = 10'b0111101111;  
13'b11000000010zzz : data\_tmp1 = 10'b0111101111;  
13'b1100000001100z : data\_tmp1 = 10'b0111101111;

30  13'b11000000011010 : data\_tmp1 = 10'b0111101111;

     13'b11000000011z11 : data\_tmp1 = 10'b0111110000;  
     13'b1100000z1110z : data\_tmp1 = 10'b0111110000;  
35  13'b1100000z11110 : data\_tmp1 = 10'b0111110000;  
     13'b110000z10zzzz : data\_tmp1 = 10'b0111110000;  
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     13'b110000z1110zz : data\_tmp1 = 10'b0111110000;  
     13'b110000z111111 : data\_tmp1 = 10'b0111110000;  
40  13'b11000010zzzzz : data\_tmp1 = 10'b0111110000;  
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     13'b1100010000zzz : data\_tmp1 = 10'b0111110000;  
     13'b1100010001000 : data\_tmp1 = 10'b0111110000;

45  13'b11000100010z1 : data\_tmp1 = 10'b0111110001;  
     13'b1100010001z10 : data\_tmp1 = 10'b0111110001;  
     13'b11000100z110z : data\_tmp1 = 10'b0111110001;  
     13'b11000100z1111 : data\_tmp1 = 10'b0111110001;  
     13'b1100010z10zzz : data\_tmp1 = 10'b0111110001;

50  13'b1100010z110zz : data\_tmp1 = 10'b0111110001;  
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     13'b110001011110z : data\_tmp1 = 10'b0111110001;  
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55  13'b11000110zzzzz : data\_tmp1 = 10'b0111110001;  
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13'b1010010010z11 : data\_tmp1 = 10'b0111100111;  
13'b101001001z10z : data\_tmp1 = 10'b0111100111;  
13'b101001001z110 : data\_tmp1 = 10'b0111100111;  
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5 13'b1010010z11111 : data\_tmp1 = 10'b0111100111;  
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13'b1010010111110 : data\_tmp1 = 10'b0111100111;  
10 13'b10100110zzzzz : data\_tmp1 = 10'b0111100111;  
  
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15 13'b1010101z1zzzz : data\_tmp1 = 10'b0111101001;  
13'b101010110zzzz : data\_tmp1 = 10'b0111101001;  
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20 13'b101011z11zzzz : data\_tmp1 = 10'b0111101010;  
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30 13'b101100001z110 : data\_tmp1 = 10'b0111101011;  
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13'b1011000111110 : data\_tmp1 = 10'b0111101011;  
13'b10110010zzzzz : data\_tmp1 = 10'b0111101011;  
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13'b101100111010z : data\_tmp1 = 10'b0111101011;  
40 13'b1011001110110 : data\_tmp1 = 10'b0111101011;  
  
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13'b101100111110z : data\_tmp1 = 10'b0111101100;  
45 13'b1011001111110 : data\_tmp1 = 10'b0111101100;  
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50 13'b101101101110z : data\_tmp1 = 10'b0111101100;  
  
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55 13'b10110111110zz : data\_tmp1 = 10'b0111101101;  
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5 13'b1001011111111 : data\_tmp1 = 10'b0111100010;  
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13'b10011001010zz : data\_tmp1 = 10'b0111100010;  
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10 13'b10011001011z1 : data\_tmp1 = 10'b0111100011;  
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13'b100110z1110zz : data\_tmp1 = 10'b0111100011;  
15 13'b100110z11110z : data\_tmp1 = 10'b0111100011;  
13'b100110z111111 : data\_tmp1 = 10'b0111100011;  
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13'b100110110zzzzz : data\_tmp1 = 10'b0111100011;  
13'b1001101111110 : data\_tmp1 = 10'b0111100011;  
20 13'b10011100000zz : data\_tmp1 = 10'b0111100011;  
  
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13'b10011100z10zz : data\_tmp1 = 10'b0111100100;  
13'b1001110z10zzz : data\_tmp1 = 10'b0111100100;  
25 13'b1001110z111zz : data\_tmp1 = 10'b0111100100;  
13'b100111010zzzz : data\_tmp1 = 10'b0111100100;  
13'b10011101110zz : data\_tmp1 = 10'b0111100100;  
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30 13'b10011110110zz : data\_tmp1 = 10'b0111100100;  
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35 13'b100111110zzzz : data\_tmp1 = 10'b0111100101;  
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40 13'b10100000zzzzzz : data\_tmp1 = 10'b0111100101;  
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5 13'b100010111110 : data\_tmp1 = 10'b0111011101;  
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10 13'b10001100z1111 : data\_tmp1 = 10'b0111011110;  
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13'b1000110z1110z : data\_tmp1 = 10'b0111011110;  
15 13'b1000110z11110 : data\_tmp1 = 10'b0111011110;  
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20 13'b10001110110zz : data\_tmp1 = 10'b0111011110;  
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25 13'b10001110zzzz : data\_tmp1 = 10'b0111011111;  
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30 13'b10010000zzzz : data\_tmp1 = 10'b0111011111;  
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40 13'b100101000z10z : data\_tmp1 = 10'b0111100001;  
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5 13'b011111011110z : data\_tmp1 = 10'b0111010111;  
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15 13'b0111111z1111 : data\_tmp1 = 10'b0111011000;  
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20  
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13'b100000010zzzz : data\_tmp1 = 10'b0111011001;  
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25 13'b10000001111zz : data\_tmp1 = 10'b0111011001;  
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13'b100000101110z : data\_tmp1 = 10'b0111011001;  
30  
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13'b10000101110zzz : data\_tmp1 = 10'b0111011011;  
40  
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13'b1000011110zz : data\_tmp1 = 10'b0111011011;  
  
45 13'b100001111z1zz : data\_tmp1 = 10'b0111011100;  
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50 13'b10001010000z1 : data\_tmp1 = 10'b0111011101;  
13'b1000101000z10 : data\_tmp1 = 10'b0111011101;  
13'b100010100z10z : data\_tmp1 = 10'b0111011101;  
13'b100010100z111 : data\_tmp1 = 10'b0111011101;  
13'b10001010z10zz : data\_tmp1 = 10'b0111011101;  
55 13'b10001010z1110 : data\_tmp1 = 10'b0111011101;  
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13'b01101110zzzz : data\_tmp1 = 10'b0111010000;  
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13'b01110001100zz : data\_tmp1 = 10'b0111010001;  
13'b011100011010z : data\_tmp1 = 10'b0111010001;  
10   13'b0111000110110 : data\_tmp1 = 10'b0111010001;

13'b011100011z111 : data\_tmp1 = 10'b0111010010;  
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15   13'b0111000111110 : data\_tmp1 = 10'b0111010010;  
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20   13'b0111001111zzz : data\_tmp1 = 10'b0111010011;  
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13'b011101010zzzz : data\_tmp1 = 10'b0111010011;  
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25   13'b0111010111z1z : data\_tmp1 = 10'b0111010100;  
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13'b011101110zzzz : data\_tmp1 = 10'b0111010100;

30   13'b0111011110zzz : data\_tmp1 = 10'b0111010100;  
13'b01110111110zz : data\_tmp1 = 10'b0111010100;  
13'b0111011111100 : data\_tmp1 = 10'b0111010100;

35   13'b01110111111z1 : data\_tmp1 = 10'b0111010101;  
13'b0111011111110 : data\_tmp1 = 10'b0111010101;  
13'b0111100zzzz : data\_tmp1 = 10'b0111010101;  
13'b0111101000000 : data\_tmp1 = 10'b0111010101;

40   13'b01111010000z1 : data\_tmp1 = 10'b0111010110;  
13'b0111101000z10 : data\_tmp1 = 10'b0111010110;  
13'b011110100z10z : data\_tmp1 = 10'b0111010110;  
13'b011110100z111 : data\_tmp1 = 10'b0111010110;  
13'b01111010z10zz : data\_tmp1 = 10'b0111010110;  
13'b01111010z1110 : data\_tmp1 = 10'b0111010110;

45   13'b0111101z10zzz : data\_tmp1 = 10'b0111010110;  
13'b0111101z1110z : data\_tmp1 = 10'b0111010110;  
13'b0111101z11111 : data\_tmp1 = 10'b0111010110;  
13'b0111101110zzzz : data\_tmp1 = 10'b0111010110;  
13'b01111011110zz : data\_tmp1 = 10'b0111010110;

50   13'b0111101111110 : data\_tmp1 = 10'b0111010110;  
13'b01111100000zz : data\_tmp1 = 10'b0111010110;  
13'b011111000010z : data\_tmp1 = 10'b0111010110;

55   13'b011111000z11z : data\_tmp1 = 10'b0111010111;  
13'b01111100z10zz : data\_tmp1 = 10'b0111010111;  
13'b01111100z110z : data\_tmp1 = 10'b0111010111;

13'b011001000zzzz : data\_tmp1 = 10'b011100101;  
13'b0110010010000 : data\_tmp1 = 10'b011100101C;

5    13'b01100100100z1 : data\_tmp1 = 10'b0111001011;  
    13'b0110010010z10 : data\_tmp1 = 10'b0111001011;  
    13'b011001001z10z : data\_tmp1 = 10'b0111001011;  
    13'b011001001z111 : data\_tmp1 = 10'b0111001011;  
    13'b0110010z110zz : data\_tmp1 = 10'b0111001011;  
    13'b0110010z11110 : data\_tmp1 = 10'b0111001011;  
10    13'b011001010zzzz : data\_tmp1 = 10'b0111001011;  
    13'b0110010110zzz : data\_tmp1 = 10'b0111001011;  
    13'b01100101110z : data\_tmp1 = 10'b0111001011;  
    13'b0110010111111 : data\_tmp1 = 10'b0111001011;  
    13'b0110011000zzz : data\_tmp1 = 10'b0111001011;  
15    13'b011001100100z : data\_tmp1 = 10'b0111001011;  
    13'b0110011001010 : data\_tmp1 = 10'b0111001011;

    13'b0110011001z11 : data\_tmp1 = 10'b0111001100;  
20    13'b01100110z110z : data\_tmp1 = 10'b0111001100;  
    13'b01100110z1110 : data\_tmp1 = 10'b0111001100;  
    13'b0110011z10zzz : data\_tmp1 = 10'b0111001100;  
    13'b0110011z110zz : data\_tmp1 = 10'b0111001100;  
    13'b0110011z11111 : data\_tmp1 = 10'b0111001100;  
    13'b011001110zzzz : data\_tmp1 = 10'b0111001100;  
25    13'b011001111110z : data\_tmp1 = 10'b0111001100;  
    13'b0110011111110 : data\_tmp1 = 10'b0111001100;  
    13'b01101000000zz : data\_tmp1 = 10'b0111001100;  
    13'b0110100000100 : data\_tmp1 = 10'b0111001100;

30    13'b01101000001z1 : data\_tmp1 = 10'b0111001101;  
    13'b011010000z110 : data\_tmp1 = 10'b0111001101;  
    13'b01101000z10zz : data\_tmp1 = 10'b0111001101;  
    13'b01101000z110z : data\_tmp1 = 10'b0111001101;  
    13'b01101000z1111 : data\_tmp1 = 10'b0111001101;  
35    13'b0110100z10zzz : data\_tmp1 = 10'b0111001101;  
    13'b0110100z11110 : data\_tmp1 = 10'b0111001101;  
    13'b011010010zzzz : data\_tmp1 = 10'b0111001101;  
    13'b01101001110zz : data\_tmp1 = 10'b0111001101;  
    13'b011010011110z : data\_tmp1 = 10'b0111001101;  
40    13'b0110100111111 : data\_tmp1 = 10'b0111001101;

    13'b01101010zzzzz : data\_tmp1 = 10'b0111001110;  
    13'b011010110zzzz : data\_tmp1 = 10'b0111001110;  
45    13'b0110101110zzz : data\_tmp1 = 10'b0111001110;  
    13'b01101011110zz : data\_tmp1 = 10'b0111001110;

    13'b01101011111zz : data\_tmp1 = 10'b0111001111;  
    13'b01101100zzzzz : data\_tmp1 = 10'b0111001111;  
    13'b011011010zzzz : data\_tmp1 = 10'b0111001111;  
50    13'b0110110110zzz : data\_tmp1 = 10'b0111001111;  
    13'b0110110111000 : data\_tmp1 = 10'b0111001111;

    13'b01101101110z1 : data\_tmp1 = 10'b0111010000;  
    13'b011011011z10 : data\_tmp1 = 10'b0111010000;  
55    13'b011011011110z : data\_tmp1 = 10'b0111010000;  
    13'b0110110111111 : data\_tmp1 = 10'b0111010000;

13'b01011010010zz : data\_tmp1 = 10'b0111000100;  
13'b010110100110z : data\_tmp1 = 10'b0111000100;  
13'b0101101001110 : data\_tmp1 = 10'b0111000100;

5    13'b01011010z1111 : data\_tmp1 = 10'b0111000101;  
13'b0101101z10zzz : data\_tmp1 = 10'b0111000101;  
13'b0101101z110zz : data\_tmp1 = 10'b0111000101;  
13'b0101101z1110z : data\_tmp1 = 10'b0111000101;  
13'b0101101z11110 : data\_tmp1 = 10'b0111000101;

10   13'b010110110zzzz : data\_tmp1 = 10'b0111000101;  
13'b0101101111111 : data\_tmp1 = 10'b0111000101;  
13'b010111000000z : data\_tmp1 = 10'b0111000101;

15   13'b0101110000z1z : data\_tmp1 = 10'b0111000110;  
13'b010111000z10z : data\_tmp1 = 10'b0111000110;  
13'b01011100z10zz : data\_tmp1 = 10'b0111000110;  
13'b01011100z11z : data\_tmp1 = 10'b0111000110;  
13'b0101110010zzz : data\_tmp1 = 10'b0111000110;

20   13'b010111001110z : data\_tmp1 = 10'b0111000110;  
13'b010111010zzzz : data\_tmp1 = 10'b0111000110;  
13'b01011101100zz : data\_tmp1 = 10'b0111000110;  
13'b010111011010z : data\_tmp1 = 10'b0111000110;  
13'b0101110110110 : data\_tmp1 = 10'b0111000110;

25   13'b010111011z111 : data\_tmp1 = 10'b0111000111;  
13'b010111011110zz : data\_tmp1 = 10'b0111000111;  
13'b010111011110z : data\_tmp1 = 10'b0111000111;  
13'b0101110111110 : data\_tmp1 = 10'b0111000111;  
13'b01011110zzzzz : data\_tmp1 = 10'b0111000111;

30   13'b0101111100zzz : data\_tmp1 = 10'b0111000111;  
13'b01011111010zz : data\_tmp1 = 10'b0111000111;

35   13'b01011111z11zz : data\_tmp1 = 10'b0111001000;  
13'b0101111110zzz : data\_tmp1 = 10'b0111001000;  
13'b01011111110zz : data\_tmp1 = 10'b0111001000;  
13'b01100000zzzzz : data\_tmp1 = 10'b0111001000;  
13'b011000010000z : data\_tmp1 = 10'b0111001000;

40   13'b0110000100z1z : data\_tmp1 = 10'b0111001001;  
13'b011000010z10z : data\_tmp1 = 10'b0111001001;  
13'b01100001z10zz : data\_tmp1 = 10'b0111001001;  
13'b01100001z111z : data\_tmp1 = 10'b0111001001;  
13'b0110000110zzz : data\_tmp1 = 10'b0111001001;

45   13'b011000011110z : data\_tmp1 = 10'b0111001001;  
13'b011000100zzzz : data\_tmp1 = 10'b0111001001;  
13'b0110001010zzz : data\_tmp1 = 10'b0111001001;  
13'b0110001011000 : data\_tmp1 = 10'b0111001001;

50   13'b01100010110z1 : data\_tmp1 = 10'b0111001010;  
13'b0110001011z10 : data\_tmp1 = 10'b0111001010;  
13'b0110001z1110z : data\_tmp1 = 10'b0111001010;  
13'b0110001z11111 : data\_tmp1 = 10'b0111001010;  
13'b011000110zzzz : data\_tmp1 = 10'b0111001010;

55   13'b0110001110zz : data\_tmp1 = 10'b0111001010;  
13'b0110001111110 : data\_tmp1 = 10'b0111001010;

13'b0101000zzzz : data\_tmp1 = 10'b0110111110;  
13'b0101000100zzz : data\_tmp1 = 10'b0110111110;  
13'b01010001010zz : data\_tmp1 = 10'b0110111110;  
13'b0101000101100 : data\_tmp1 = 10'b0110111110;  
  
5       13'b01010001011z1 : data\_tmp1 = 10'b0110111111;  
      13'b01010001z1110 : data\_tmp1 = 10'b0110111111;  
      13'b0101000110zzz : data\_tmp1 = 10'b0110111111;  
      13'b01010001110zz : data\_tmp1 = 10'b0110111111;  
10      13'b010100011110z : data\_tmp1 = 10'b0110111111;  
      13'b0101000111111 : data\_tmp1 = 10'b0110111111;  
      13'b010100100zzzz : data\_tmp1 = 10'b0110111111;  
      13'b0101001010zzz : data\_tmp1 = 10'b0110111111;  
      13'b010100101100z : data\_tmp1 = 10'b0110111111;  
15      13'b0101001011010 : data\_tmp1 = 10'b0110111111;  
  
      13'b01010010111z11 : data\_tmp1 = 10'b0111000000;  
      13'b0101001z1110z : data\_tmp1 = 10'b0111000000;  
20      13'b0101001z11110 : data\_tmp1 = 10'b0111000000;  
      13'b0101001110zzz : data\_tmp1 = 10'b0111000000;  
      13'b01010011110zz : data\_tmp1 = 10'b0111000000;  
      13'b0101001111111 : data\_tmp1 = 10'b0111000000;  
25      13'b0101010000zzz : data\_tmp1 = 10'b0111000000;  
      13'b010101000100z : data\_tmp1 = 10'b0111000000;  
  
      13'b0101010001z1z : data\_tmp1 = 10'b0111000001;  
      13'b01010100z110z : data\_tmp1 = 10'b0111000001;  
30      13'b0101010z10zzz : data\_tmp1 = 10'b0111000001;  
      13'b01010100110zz : data\_tmp1 = 10'b0111000001;  
      13'b01010100111z : data\_tmp1 = 10'b0111000001;  
      13'b010101010zzzz : data\_tmp1 = 10'b0111000001;  
      13'b010101011100z : data\_tmp1 = 10'b0111000001;  
35      13'b0101010111z1z : data\_tmp1 = 10'b0111000010;  
      13'b010101011110z : data\_tmp1 = 10'b0111000010;  
      13'b01010110zzzz : data\_tmp1 = 10'b0111000010;  
      13'b0101011110zzz : data\_tmp1 = 10'b0111000010;  
      13'b010101111100z : data\_tmp1 = 10'b0111000010;  
40      13'b0101011111010 : data\_tmp1 = 10'b0111000010;  
  
      13'b01010111101z11 : data\_tmp1 = 10'b0111000011;  
      13'b01010111z110z : data\_tmp1 = 10'b0111000011;  
45      13'b01010111z1110 : data\_tmp1 = 10'b0111000011;  
      13'b0101011110zzz : data\_tmp1 = 10'b0111000011;  
      13'b010101111110z : data\_tmp1 = 10'b0111000011;  
      13'b010110000zzzz : data\_tmp1 = 10'b0111000011;  
      13'b0101100010zzz : data\_tmp1 = 10'b0111000011;  
50      13'b01011000110zz : data\_tmp1 = 10'b0111000011;  
  
      13'b0101100z111zz : data\_tmp1 = 10'b0111000100;  
      13'b010110010zzzz : data\_tmp1 = 10'b0111000100;  
      13'b0101100110zzz : data\_tmp1 = 10'b0111000100;  
55      13'b01011001110zz : data\_tmp1 = 10'b0111000100;  
      13'b0101101000zzz : data\_tmp1 = 10'b0111000100;

13'b000110100zz : data\_tmp1 = 10'b0110110110;  
13'b0001101010z : data\_tmp1 = 10'b0110110110;  
13'b100011010110 : data\_tmp1 = 10'b0110110110;

5 13'b10001101z111 : data\_tmp1 = 10'b0110110111;  
13'b0100011z110zz : data\_tmp1 = 10'b0110110111;  
13'b0100011z1110z : data\_tmp1 = 10'b0110110111;  
13'b0100011z11110 : data\_tmp1 = 10'b0110110111;  
13'b010001110zzzz : data\_tmp1 = 10'b0110110111;  
10 13'b0100011110zzz : data\_tmp1 = 10'b0110110111;

13'b0100011111111 : data\_tmp1 = 10'b0110111000;  
13'b01001000zzzzz : data\_tmp1 = 10'b0110111000;  
13'b0100100100zzz : data\_tmp1 = 10'b0110111000;

15 13'b01001001z1zzz : data\_tmp1 = 10'b0110111001;  
13'b0100100110zzz : data\_tmp1 = 10'b0110111001;  
13'b010010100zzzz : data\_tmp1 = 10'b0110111001;  
13'b0100101010000 : data\_tmp1 = 10'b0110111001;

20 13'b01001010100z1 : data\_tmp1 = 10'b0110111010;  
13'b0100101010z10 : data\_tmp1 = 10'b0110111010;  
13'b010010101z10z : data\_tmp1 = 10'b0110111010;  
13'b010010101z111 : data\_tmp1 = 10'b0110111010;

25 13'b0100101z110zz : data\_tmp1 = 10'b0110111010;  
13'b0100101011110 : data\_tmp1 = 10'b0110111010;  
13'b010010110zzzz : data\_tmp1 = 10'b0110111010;  
13'b0100101110zzz : data\_tmp1 = 10'b0110111010;

30 13'b01001011111zz : data\_tmp1 = 10'b0110111011;  
13'b01001100zzzzz : data\_tmp1 = 10'b0110111011;  
13'b01001101000zz : data\_tmp1 = 10'b0110111011;  
13'b010011010010z : data\_tmp1 = 10'b0110111011;  
13'b0100110100110 : data\_tmp1 = 10'b0110111011;

35 13'b010011010z111 : data\_tmp1 = 10'b0110111100;  
13'b01001101z10zz : data\_tmp1 = 10'b0110111100;  
13'b01001101z110z : data\_tmp1 = 10'b0110111100;  
13'b01001101z1110 : data\_tmp1 = 10'b0110111100;

40 13'b0100110110zzz : data\_tmp1 = 10'b0110111100;  
13'b0100110111111 : data\_tmp1 = 10'b0110111100;  
13'b010011100zzzz : data\_tmp1 = 10'b0110111100;  
13'b010011101000z : data\_tmp1 = 10'b0110111100;  
13'b0100111010010 : data\_tmp1 = 10'b0110111100;

45 13'b0100111010z11 : data\_tmp1 = 10'b0110111101;  
13'b010011101z10z : data\_tmp1 = 10'b0110111101;  
13'b010011101z110 : data\_tmp1 = 10'b0110111101;  
13'b0100111z110zz : data\_tmp1 = 10'b0110111101;

50 13'b0100111011111 : data\_tmp1 = 10'b0110111101;  
13'b010011110zzzz : data\_tmp1 = 10'b0110111101;  
13'b0100111110zzz : data\_tmp1 = 10'b0110111101;  
13'b010011111110z : data\_tmp1 = 10'b0110111101;  
13'b0100111111110 : data\_tmp1 = 10'b0110111101;

55 13'b0100111111111 : data\_tmp1 = 10'b0110111110;

13'b0011110010zzz : data\_tmp1 = 10'b0110101110;  
13'b00111100110zz : data\_tmp1 = 10'b0110101110;  
13'b0011110011111 : data\_tmp1 = 10'b0110101110;  
13'b0011110100zzz : data\_tmp1 = 10'b0110101110;  
5 13'b00111101010zz : data\_tmp1 = 10'b0110101110;  
13'b0011110101100 : data\_tmp1 = 10'b0110101110;  
  
13'b00111101011z1 : data\_tmp1 = 10'b0110101111;  
13'b00111101z1110 : data\_tmp1 = 10'b0110101111;  
10 13'b0011110110zzz : data\_tmp1 = 10'b0110101111;  
13'b00111101110zz : data\_tmp1 = 10'b0110101111;  
13'b001111011110z : data\_tmp1 = 10'b0110101111;  
13'b0011110111111 : data\_tmp1 = 10'b0110101111;  
13'b001111100zzzz : data\_tmp1 = 10'b0110101111;  
15  
13'b001111101zzzz : data\_tmp1 = 10'b0110110000;  
13'b001111110zzzz : data\_tmp1 = 10'b0110110000;  
13'b00111111100zz : data\_tmp1 = 10'b0110110000;  
  
20 13'b001111111z1zz : data\_tmp1 = 10'b0110110001;  
13'b00111111110zz : data\_tmp1 = 10'b0110110001;  
13'b010000000zzzz : data\_tmp1 = 10'b0110110001;  
13'b0100000010zzz : data\_tmp1 = 10'b0110110001;  
  
25 13'b0100000011zzz : data\_tmp1 = 10'b0110110010;  
13'b010000010zzzz : data\_tmp1 = 10'b0110110010;  
13'b0100000110zzz : data\_tmp1 = 10'b0110110010;  
13'b01000001110zz : data\_tmp1 = 10'b0110110010;  
13'b0100000111100 : data\_tmp1 = 10'b0110110010;  
30  
13'b01000001111z1 : data\_tmp1 = 10'b0110110011;  
13'b0100000111110 : data\_tmp1 = 10'b0110110011;  
13'b01000010zzzzz : data\_tmp1 = 10'b0110110011;  
13'b010000110000z : data\_tmp1 = 10'b0110110011;  
35  
13'b0100001100z1z : data\_tmp1 = 10'b0110110100;  
13'b010000110z10z : data\_tmp1 = 10'b0110110100;  
13'b01000011z10zz : data\_tmp1 = 10'b0110110100;  
13'b01000011z111z : data\_tmp1 = 10'b0110110100;  
40 13'b0100001110zzz : data\_tmp1 = 10'b0110110100;  
13'b010000111110z : data\_tmp1 = 10'b0110110100;  
13'b0100010000zzz : data\_tmp1 = 10'b0110110100;  
  
45 13'b01000100z1zzz : data\_tmp1 = 10'b0110110101;  
13'b0100010010zzz : data\_tmp1 = 10'b0110110101;  
13'b0100010100zzz : data\_tmp1 = 10'b0110110101;  
13'b01000101010zz : data\_tmp1 = 10'b0110110101;  
13'b010001010110z : data\_tmp1 = 10'b0110110101;  
13'b0100010101110 : data\_tmp1 = 10'b0110110101;  
50  
13'b01000101z1111 : data\_tmp1 = 10'b0110110110;  
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13'b01000101110zz : data\_tmp1 = 10'b0110110110;  
13'b010001011110z : data\_tmp1 = 10'b0110110110;  
55 13'b0100010111110 : data\_tmp1 = 10'b0110110110;  
13'b010001100zzzz : data\_tmp1 = 10'b0110110110;

13'b001101010100z : data\_tmp1 = 10'b0110100110;  
13'b0011010101010 : data\_tmp1 = 10'b0110100110;

5   13'b0011010101z11 : data\_tmp1 = 10'b0110100111;  
13'b00110101z110z : data\_tmp1 = 10'b0110100111;  
13'b00110101z1110 : data\_tmp1 = 10'b0110100111;  
13'b0011010110zzz : data\_tmp1 = 10'b0110100111;  
13'b00110101110zz : data\_tmp1 = 10'b0110100111;  
13'b0011010111111 : data\_tmp1 = 10'b0110100111;  
10   13'b0011011000zzz : data\_tmp1 = 10'b0110100111;  
13'b001101100100z : data\_tmp1 = 10'b0110100111;

15   13'b0011011001z1z : data\_tmp1 = 10'b0110101000;  
13'b00110110z110z : data\_tmp1 = 10'b0110101000;  
13'b0011011010zzz : data\_tmp1 = 10'b0110101000;  
13'b00110110110zz : data\_tmp1 = 10'b0110101000;  
13'b00110110111z : data\_tmp1 = 10'b0110101000;  
13'b0011011100zzz : data\_tmp1 = 10'b0110101000;  
13'b00110111101000 : data\_tmp1 = 10'b0110101000;

20   13'b001101111010z1 : data\_tmp1 = 10'b0110101001;  
13'b00110111101z10 : data\_tmp1 = 10'b0110101001;  
13'b00110111z110z : data\_tmp1 = 10'b0110101001;  
13'b00110111z1111 : data\_tmp1 = 10'b0110101001;  
25   13'b0011011110zzz : data\_tmp1 = 10'b0110101001;  
13'b00110111110zz : data\_tmp1 = 10'b0110101001;  
13'b0011011111110 : data\_tmp1 = 10'b0110101001;  
13'b0011100000zzz : data\_tmp1 = 10'b0110101001;

30   13'b00111000z1zzz : data\_tmp1 = 10'b0110101010;  
13'b0011100010zzz : data\_tmp1 = 10'b0110101010;  
13'b0011100100zzz : data\_tmp1 = 10'b0110101010;

35   13'b00111001z1zzz : data\_tmp1 = 10'b0110101011;  
13'b0011100110zzz : data\_tmp1 = 10'b0110101011;  
13'b0011101000zzz : data\_tmp1 = 10'b0110101011;

40   13'b00111010z1zzz : data\_tmp1 = 10'b0110101100;  
13'b0011101010zzz : data\_tmp1 = 10'b0110101100;  
13'b001110101100zzz : data\_tmp1 = 10'b0110101100;  
13'b0011101011000 : data\_tmp1 = 10'b0110101100;

45   13'b00111011010z1 : data\_tmp1 = 10'b0110101101;  
13'b0011101101z10 : data\_tmp1 = 10'b0110101101;  
13'b00111011z110z : data\_tmp1 = 10'b0110101101;  
13'b00111011z1111 : data\_tmp1 = 10'b0110101101;  
13'b0011101110zzz : data\_tmp1 = 10'b0110101101;  
13'b00111011110zz : data\_tmp1 = 10'b0110101101;  
13'b0011101111110 : data\_tmp1 = 10'b0110101101;

50   13'b0011110000zzz : data\_tmp1 = 10'b0110101101;  
13'b001111000100z : data\_tmp1 = 10'b0110101101;  
13'b0011110001010 : data\_tmp1 = 10'b0110101101;

55   13'b0011110001z11 : data\_tmp1 = 10'b0110101110;  
13'b00111100z110z : data\_tmp1 = 10'b0110101110;  
13'b00111100z1110 : data\_tmp1 = 10'b0110101110;

13'b001011011z10z : data\_tmp1 = 10'b0110011110;  
13'b001011011z111 : data\_tmp1 = 10'b0110011110;  
13'b00101101110zz : data\_tmp1 = 10'b0110011110;  
13'b0010110111110 : data\_tmp1 = 10'b0110011110;  
5 13'b0010111000zzz : data\_tmp1 = 10'b0110011110;  
13'b001011100100z : data\_tmp1 = 10'b0110011110;  
13'b0010111001010 : data\_tmp1 = 10'b0110011110;  
  
13'b0010111001z11 : data\_tmp1 = 10'b0110011111;  
10 13'b00101110z110z : data\_tmp1 = 10'b0110011111;  
13'b00101110z1110 : data\_tmp1 = 10'b0110011111;  
13'b0010111010zzz : data\_tmp1 = 10'b0110011111;  
13'b00101110110zz : data\_tmp1 = 10'b0110011111;  
13'b0010111011111 : data\_tmp1 = 10'b0110011111;  
15 13'b00101111000zz : data\_tmp1 = 10'b0110011111;  
13'b0010111100100 : data\_tmp1 = 10'b0110011111;  
  
13'b00101111001z1 : data\_tmp1 = 10'b0110100000;  
20 13'b001011110z110 : data\_tmp1 = 10'b0110100000;  
13'b00101111z10zz : data\_tmp1 = 10'b0110100000;  
13'b00101111z110z : data\_tmp1 = 10'b0110100000;  
13'b00101111z1111 : data\_tmp1 = 10'b0110100000;  
13'b0010111110zzz : data\_tmp1 = 10'b0110100000;  
25 13'b0010111111110 : data\_tmp1 = 10'b0110100000;  
  
13'b001100000zzzz : data\_tmp1 = 10'b0110100001;  
13'b0011000010zzz : data\_tmp1 = 10'b0110100001;  
13'b00110000110zz : data\_tmp1 = 10'b0110100001;  
  
30 13'b00110000111zz : data\_tmp1 = 10'b0110100010;  
13'b001100010zzzz : data\_tmp1 = 10'b0110100010;  
13'b00110001100zz : data\_tmp1 = 10'b0110100010;  
13'b001100011010z : data\_tmp1 = 10'b0110100010;  
13'b0011000110110 : data\_tmp1 = 10'b0110100010;  
35 13'b001100011z111 : data\_tmp1 = 10'b0110100011;  
13'b00110001110zz : data\_tmp1 = 10'b0110100011;  
13'b001100011110z : data\_tmp1 = 10'b0110100011;  
13'b0011000111110 : data\_tmp1 = 10'b0110100011;  
40 13'b001100100zzzz : data\_tmp1 = 10'b0110100011;  
13'b00110010100zz : data\_tmp1 = 10'b0110100011;  
  
13'b001100101z1zz : data\_tmp1 = 10'b0110100100;  
13'b00110010110zz : data\_tmp1 = 10'b0110100100;  
45 13'b001100110zzzz : data\_tmp1 = 10'b0110100100;  
  
13'b001100111zzzz : data\_tmp1 = 10'b0110100101;  
13'b0011010000zzz : data\_tmp1 = 10'b0110100101;  
13'b00110100010zz : data\_tmp1 = 10'b0110100101;  
50 13'b001101000110z : data\_tmp1 = 10'b0110100101;  
  
13'b00110100z111z : data\_tmp1 = 10'b0110100110;  
13'b0011010010zzz : data\_tmp1 = 10'b0110100110;  
13'b00110100110zz : data\_tmp1 = 10'b0110100110;  
55 13'b001101001110z : data\_tmp1 = 10'b0110100110;  
13'b0011010100zzz : data\_tmp1 = 10'b0110100110;

13'b001001100z11z : data\_tmp1 = 10'b0110010100;  
13'b00100110z10zz : data\_tmp1 = 10'b0110010100;  
13'b001001100110z : data\_tmp1 = 10'b0110010100;  
13'b0010011010zzz : data\_tmp1 = 10'b0110010100;  
5 13'b00100110111zz : data\_tmp1 = 10'b0110010101;  
13'b001001110zzzz : data\_tmp1 = 10'b0110010101;  
13'b001001111000z : data\_tmp1 = 10'b0110010101;  
10 13'b0010011110z1z : data\_tmp1 = 10'b0110010110;  
13'b001001111z10z : data\_tmp1 = 10'b0110010110;  
13'b00100111110zz : data\_tmp1 = 10'b0110010110;  
13'b001001111111z : data\_tmp1 = 10'b0110010110;  
13'b0010100000zzz : data\_tmp1 = 10'b0110010110;  
15 13'b0010100001zzz : data\_tmp1 = 10'b0110010111;  
13'b0010100010zzz : data\_tmp1 = 10'b0110010111;  
13'b00101000110zz : data\_tmp1 = 10'b0110010111;  
13'b001010001110z : data\_tmp1 = 10'b0110010111;  
20 13'b0010100011110 : data\_tmp1 = 10'b0110010111;  
  
13'b0010100011111 : data\_tmp1 = 10'b0110011000;  
13'b001010010zzzz : data\_tmp1 = 10'b0110011000;  
13'b00101001100zz : data\_tmp1 = 10'b0110011000;  
25 13'b001010011010z : data\_tmp1 = 10'b0110011000;  
  
13'b001010011z11z : data\_tmp1 = 10'b0110011001;  
13'b00101001110zz : data\_tmp1 = 10'b0110011001;  
13'b001010011110z : data\_tmp1 = 10'b0110011001;  
30 13'b0010101000zzz : data\_tmp1 = 10'b0110011001;  
13'b00101010010zz : data\_tmp1 = 10'b0110011001;  
13'b001010100110z : data\_tmp1 = 10'b0110011001;  
  
13'b00101010z11z : data\_tmp1 = 10'b0110011010;  
35 13'b0010101010zzz : data\_tmp1 = 10'b0110011010;  
13'b00101010110zz : data\_tmp1 = 10'b0110011010;  
13'b001010101110z : data\_tmp1 = 10'b0110011010;  
13'b00101011000zz : data\_tmp1 = 10'b0110011010;  
13'b001010110010z : data\_tmp1 = 10'b0110011010;  
40 13'b001010110z11z : data\_tmp1 = 10'b0110011011;  
13'b00101011z10zz : data\_tmp1 = 10'b0110011011;  
13'b00101011z110z : data\_tmp1 = 10'b0110011011;  
13'b0010101110zzz : data\_tmp1 = 10'b0110011011;  
45 13'b001010111110 : data\_tmp1 = 10'b0110011011;  
  
13'b0010101111111 : data\_tmp1 = 10'b0110011100;  
13'b001011000zzzz : data\_tmp1 = 10'b0110011100;  
13'b0010110010zzz : data\_tmp1 = 10'b0110011100;  
50 13'b0010110011zzz : data\_tmp1 = 10'b0110011101;  
13'b001011010zzzz : data\_tmp1 = 10'b0110011101;  
13'b0010110110000 : data\_tmp1 = 10'b0110011101;  
  
55 13'b00101101100z1 : data\_tmp1 = 10'b0110011110;  
13'b0010110110z10 : data\_tmp1 = 10'b0110011110;

13'b001000000000000 : data\_tmp1 = 10'b0110001011;  
13'b001000000000001 : data\_tmp1 = 10'b0110001011;  
13'b001000000000010 : data\_tmp1 = 10'b0110001011;  
13'b001000000000011 : data\_tmp1 = 10'b0110001011;  
5 13'b0010000000000110 : data\_tmp1 = 10'b0110001011;  
13'b0010000000000110zz : data\_tmp1 = 10'b0110001011;  
13'b0010000000000110z : data\_tmp1 = 10'b0110001011;  
  
10 13'b001000000000011zz : data\_tmp1 = 10'b0110001100;  
13'b001000000000010zz : data\_tmp1 = 10'b0110001100;  
13'b00100000000001010z : data\_tmp1 = 10'b0110001100;  
13'b001000000000010zzz : data\_tmp1 = 10'b0110001100;  
  
15 13'b001000000000011zzz : data\_tmp1 = 10'b0110001101;  
13'b001000000000010zzz : data\_tmp1 = 10'b0110001101;  
13'b00100000000001010zz : data\_tmp1 = 10'b0110001101;  
  
20 13'b00100000000001011zz : data\_tmp1 = 10'b0110001110;  
13'b00100000000001010zzz : data\_tmp1 = 10'b0110001110;  
13'b001000000000010110zz : data\_tmp1 = 10'b0110001110;  
13'b0010000000000101110z : data\_tmp1 = 10'b0110001110;  
13'b0010000000000101110 : data\_tmp1 = 10'b0110001110;  
  
25 13'b00100000000001011111 : data\_tmp1 = 10'b0110001111;  
13'b0010000000000110zzzz : data\_tmp1 = 10'b0110001111;  
13'b0010000000000111000z : data\_tmp1 = 10'b0110001111;  
13'b00100000000001110010 : data\_tmp1 = 10'b0110001111;  
  
30 13'b00100000000001110z11 : data\_tmp1 = 10'b0110010000;  
13'b0010000000000111z10z : data\_tmp1 = 10'b0110010000;  
13'b0010000000000111z110 : data\_tmp1 = 10'b0110010000;  
13'b001000000000011110zz : data\_tmp1 = 10'b0110010000;  
13'b00100000000001111111 : data\_tmp1 = 10'b0110010000;  
13'b001000000000010000zz : data\_tmp1 = 10'b0110010000;  
35 13'b001000000000010z : data\_tmp1 = 10'b0110010000;  
13'b0010000000000110 : data\_tmp1 = 10'b0110010000;  
  
40 13'b0010000000000100z111 : data\_tmp1 = 10'b0110010001;  
13'b001000000000010z10zz : data\_tmp1 = 10'b0110010001;  
13'b0010000000000110z : data\_tmp1 = 10'b0110010001;  
13'b00100000000001110 : data\_tmp1 = 10'b0110010001;  
13'b001000000000010010zzz : data\_tmp1 = 10'b0110010001;  
  
45 13'b00100000000001011zz : data\_tmp1 = 10'b0110010010;  
13'b00100000000001010zzzz : data\_tmp1 = 10'b0110010010;  
13'b001000000000010110000 : data\_tmp1 = 10'b0110010010;  
  
50 13'b0010000000000101100z1 : data\_tmp1 = 10'b0110010011;  
13'b001000000000010110z10 : data\_tmp1 = 10'b0110010011;  
55 13'b001000000000010110z10z : data\_tmp1 = 10'b0110010011;  
13'b001000000000010110z111 : data\_tmp1 = 10'b0110010011;  
13'b0010000000000101110zz : data\_tmp1 = 10'b0110010011;  
13'b00100000000001011110 : data\_tmp1 = 10'b0110010011;  
13'b001000000000010110000zz : data\_tmp1 = 10'b0110010011;  
13'b001000000000010110010z : data\_tmp1 = 10'b0110010011;

13'b001101111z1z : data\_tmp1 = 10'b0110000010;  
13'b000110111110z : data\_tmp1 = 10'b0110000010;  
13'b0001110000zzz : data\_tmp1 = 10'b0110000010;  
13'b000111000100z : data\_tmp1 = 10'b0110000010;  
5  
13'b0001110001z1z : data\_tmp1 = 10'b0110000011;  
13'b000111000110z : data\_tmp1 = 10'b0110000011;  
13'b0001110010zzz : data\_tmp1 = 10'b0110000011;  
13'b000111001100z : data\_tmp1 = 10'b0110000011;  
10  
13'b0001110011z1z : data\_tmp1 = 10'b0110000100;  
13'b000111001110z : data\_tmp1 = 10'b0110000100;  
13'b0001110100zzz : data\_tmp1 = 10'b0110000100;  
13'b000111010100z : data\_tmp1 = 10'b0110000100;  
15  
13'b0001110101010 : data\_tmp1 = 10'b0110000100;  
  
13'b0001110101z11 : data\_tmp1 = 10'b0110000101;  
13'b000111010110z : data\_tmp1 = 10'b0110000101;  
13'b0001110101110 : data\_tmp1 = 10'b0110000101;  
20  
13'b0001110110zzz : data\_tmp1 = 10'b0110000101;  
13'b000111011100z : data\_tmp1 = 10'b0110000101;  
13'b0001110111010 : data\_tmp1 = 10'b0110000101;  
  
13'b0001110111z11 : data\_tmp1 = 10'b0110000110;  
25  
13'b000111011110z : data\_tmp1 = 10'b0110000110;  
13'b0001110111110 : data\_tmp1 = 10'b0110000110;  
13'b0001111000zzz : data\_tmp1 = 10'b0110000110;  
13'b00011110010zz : data\_tmp1 = 10'b0110000110;  
  
30  
13'b00011110011zz : data\_tmp1 = 10'b0110000111;  
13'b0001111010zzz : data\_tmp1 = 10'b0110000111;  
13'b00011110110zz : data\_tmp1 = 10'b0110000111;  
13'b0001111011100 : data\_tmp1 = 10'b0110000111;  
  
35  
13'b00011110111z1 : data\_tmp1 = 10'b0110001000;  
13'b0001111011110 : data\_tmp1 = 10'b0110001000;  
13'b0001111100zzz : data\_tmp1 = 10'b0110001000;  
13'b00011111010zz : data\_tmp1 = 10'b0110001000;  
13'b000111110110z : data\_tmp1 = 10'b0110001000;  
40  
13'b0001111101110 : data\_tmp1 = 10'b0110001000;  
  
13'b00011111z1111 : data\_tmp1 = 10'b0110001001;  
13'b0001111110zzz : data\_tmp1 = 10'b0110001001;  
13'b00011111110zz : data\_tmp1 = 10'b0110001001;  
45  
13'b0001111111110z : data\_tmp1 = 10'b0110001001;  
13'b00011111111110 : data\_tmp1 = 10'b0110001001;  
13'b0010000000000 : data\_tmp1 = 10'b0110001001;  
  
13'b00100000000z1 : data\_tmp1 = 10'b0110001010;  
50  
13'b0010000000z10 : data\_tmp1 = 10'b0110001010;  
13'b001000000z10z : data\_tmp1 = 10'b0110001010;  
13'b001000000z111 : data\_tmp1 = 10'b0110001010;  
13'b00100000010zz : data\_tmp1 = 10'b0110001010;  
13'b0010000001110 : data\_tmp1 = 10'b0110001010;  
55  
13'b001000001000z : data\_tmp1 = 10'b0110001010;  
13'b0010000010010 : data\_tmp1 = 10'b0110001010;

13'b000101110110z : data\_tmp1 = 10'b0101111000;  
13'b0001011101110 : data\_tmp1 = 10'b0101111000;  
13'b0001011110zzz : data\_tmp1 = 10'b0101111000;

5   13'b0001011111zzz : data\_tmp1 = 10'b0101111001;  
13'b00011000000zz : data\_tmp1 = 10'b0101111001;  
13'b0001100000100 : data\_tmp1 = 10'b0101111001;

10   13'b00011000001z1 : data\_tmp1 = 10'b0101111010;  
13'b000110000z110 : data\_tmp1 = 10'b0101111010;  
13'b00011000010zz : data\_tmp1 = 10'b0101111010;  
13'b000110000110z : data\_tmp1 = 10'b0101111010;  
13'b0001100001111 : data\_tmp1 = 10'b0101111010;  
13'b000110001000z : data\_tmp1 = 10'b0101111010;  
15   13'b0001100010010 : data\_tmp1 = 10'b0101111010;

13'b0001100010z11 : data\_tmp1 = 10'b0101111011;  
13'b000110001z10z : data\_tmp1 = 10'b0101111011;  
13'b000110001z110 : data\_tmp1 = 10'b0101111011;

20   13'b00011000110zz : data\_tmp1 = 10'b0101111011;  
13'b0001100011111 : data\_tmp1 = 10'b0101111011;  
13'b0001100100000 : data\_tmp1 = 10'b0101111011;

13'b00011001000z1 : data\_tmp1 = 10'b0101111100;  
25   13'b0001100100z10 : data\_tmp1 = 10'b0101111100;  
13'b000110010z10z : data\_tmp1 = 10'b0101111100;  
13'b0001100100111 : data\_tmp1 = 10'b0101111100;  
13'b00011001010zz : data\_tmp1 = 10'b0101111100;  
13'b0001100101110 : data\_tmp1 = 10'b0101111100;

30   13'b0001100101111 : data\_tmp1 = 10'b0101111101;  
13'b0001100110zzz : data\_tmp1 = 10'b0101111101;  
13'b00011001110zz : data\_tmp1 = 10'b0101111101;  
13'b000110011110z : data\_tmp1 = 10'b0101111101;

35   13'b000110011111z : data\_tmp1 = 10'b0101111110;  
13'b0001101000zzz : data\_tmp1 = 10'b0101111110;  
13'b00011010010zz : data\_tmp1 = 10'b0101111110;  
13'b0001101001100 : data\_tmp1 = 10'b0101111110;

40   13'b00011010011z1 : data\_tmp1 = 10'b0101111111;  
13'b0001101001110 : data\_tmp1 = 10'b0101111111;  
13'b0001101010zzz : data\_tmp1 = 10'b0101111111;  
13'b00011010110zz : data\_tmp1 = 10'b0101111111;

45   13'b00011010111zz : data\_tmp1 = 10'b0110000000;  
13'b0001101100zzz : data\_tmp1 = 10'b0110000000;  
13'b000110110100z : data\_tmp1 = 10'b0110000000;  
13'b0001101101010 : data\_tmp1 = 10'b0110000000;

50   13'b0001101101z11 : data\_tmp1 = 10'b0110000001;  
13'b000110110110z : data\_tmp1 = 10'b0110000001;  
13'b0001101101110 : data\_tmp1 = 10'b0110000001;  
13'b0001101110zzz : data\_tmp1 = 10'b0110000001;

55   13'b000110111100z : data\_tmp1 = 10'b0110000001;

13'b00010010111z1 : data\_tmp1 = 10'b0101101100;  
13'b0001001011110 : data\_tmp1 = 10'b0101101100;  
13'b00010011000zz : data\_tmp1 = 10'b0101101100;  
13'b000100110010z : data\_tmp1 = 10'b0101101100;  
5 13'b0001001100110 : data\_tmp1 = 10'b0101101100;  
  
13'b000100110z111 : data\_tmp1 = 10'b0101101101;  
13'b00010011010zz : data\_tmp1 = 10'b0101101101;  
13'b000100110110z : data\_tmp1 = 10'b0101101101;  
10 13'b0001001101110 : data\_tmp1 = 10'b0101101101;  
13'b000100111000z : data\_tmp1 = 10'b0101101101;  
  
13'b0001001110z1z : data\_tmp1 = 10'b0101101110;  
13'b000100111010z : data\_tmp1 = 10'b0101101110;  
15 13'b00010011110zz : data\_tmp1 = 10'b0101101110;  
13'b0001001111100 : data\_tmp1 = 10'b0101101110;  
  
13'b00010011111z1 : data\_tmp1 = 10'b0101101111;  
13'b0001001111110 : data\_tmp1 = 10'b0101101111;  
20 13'b000101000zzz : data\_tmp1 = 10'b0101101111;  
13'b0001010001000 : data\_tmp1 = 10'b0101101111;  
  
13'b00010100010z1 : data\_tmp1 = 10'b0101110000;  
13'b0001010001z10 : data\_tmp1 = 10'b0101110000;  
25 13'b000101000110z : data\_tmp1 = 10'b0101110000;  
13'b0001010001111 : data\_tmp1 = 10'b0101110000;  
13'b00010100100zz : data\_tmp1 = 10'b0101110000;  
  
13'b000101001z1zz : data\_tmp1 = 10'b0101110001;  
30 13'b00010100110zz : data\_tmp1 = 10'b0101110001;  
  
13'b0001010100zzz : data\_tmp1 = 10'b0101110010;  
13'b00010101010zz : data\_tmp1 = 10'b0101110010;  
  
35 13'b00010101011zz : data\_tmp1 = 10'b0101110011;  
13'b0001010110zzz : data\_tmp1 = 10'b0101110011;  
  
13'b0001010111zzz : data\_tmp1 = 10'b0101110100;  
13'b00010110000zz : data\_tmp1 = 10'b0101110100;  
40 13'b000101100z1zz : data\_tmp1 = 10'b0101110101;  
13'b00010110010zz : data\_tmp1 = 10'b0101110101;  
13'b0001011010000 : data\_tmp1 = 10'b0101110101;  
  
45 13'b00010110100z1 : data\_tmp1 = 10'b0101110110;  
13'b0001011010z10 : data\_tmp1 = 10'b0101110110;  
13'b000101101z10z : data\_tmp1 = 10'b0101110110;  
13'b0001011010111 : data\_tmp1 = 10'b0101110110;  
13'b00010110110zz : data\_tmp1 = 10'b0101110110;  
50 13'b00010110111z : data\_tmp1 = 10'b0101110111;  
13'b0001011100zzz : data\_tmp1 = 10'b0101110111;  
13'b000101110100z : data\_tmp1 = 10'b0101110111;  
13'b0001011101010 : data\_tmp1 = 10'b0101110111;  
55 13'b0001011101z11 : data\_tmp1 = 10'b0101111000;

13'b0000111100z10 : data\_tmp1 = 10'b0101011111;  
13'b000011110010z : data\_tmp1 = 10'b0101011111;  
13'b0000111100111 : data\_tmp1 = 10'b0101011111;  
13'b000011110100z : data\_tmp1 = 10'b0101011111;

5       13'b0000111101z1z : data\_tmp1 = 10'b0101100000;  
      13'b000011110110z : data\_tmp1 = 10'b0101100000;  
      13'b000011111000z : data\_tmp1 = 10'b0101100000;

10      13'b0000111110z1z : data\_tmp1 = 10'b0101100001;  
      13'b000011111010z : data\_tmp1 = 10'b0101100001;  
      13'b000011111100z : data\_tmp1 = 10'b0101100001;  
      13'b0000111111010 : data\_tmp1 = 10'b0101100001;

15      13'b0000111111z11 : data\_tmp1 = 10'b0101100010;  
      13'b000011111110z : data\_tmp1 = 10'b0101100010;  
      13'b0000111111110 : data\_tmp1 = 10'b0101100010;  
      13'b0001000000zz : data\_tmp1 = 10'b0101100010;

20      13'b00010000001zz : data\_tmp1 = 10'b0101100011;  
      13'b00010000010zz : data\_tmp1 = 10'b0101100011;  
      13'b0001000001100 : data\_tmp1 = 10'b0101100011;

25      13'b00010000011z1 : data\_tmp1 = 10'b0101100100;  
      13'b0001000001110 : data\_tmp1 = 10'b0101100100;  
      13'b00010000100zz : data\_tmp1 = 10'b0101100100;  
      13'b000100001010z : data\_tmp1 = 10'b0101100100;  
      13'b0001000010110 : data\_tmp1 = 10'b0101100100;

30      13'b000100001z111 : data\_tmp1 = 10'b0101100101;  
      13'b00010000110zz : data\_tmp1 = 10'b0101100101;  
      13'b000100001110z : data\_tmp1 = 10'b0101100101;  
      13'b0001000011110 : data\_tmp1 = 10'b0101100101;

35      13'b0001000100zzz : data\_tmp1 = 10'b0101100110;  
      13'b000100010100z : data\_tmp1 = 10'b0101100110;

         13'b0001000101z1z : data\_tmp1 = 10'b0101100111;  
         13'b000100010110z : data\_tmp1 = 10'b0101100111;

40      13'b0001000100zz : data\_tmp1 = 10'b0101100111;

         13'b00010001101zz : data\_tmp1 = 10'b0101101000;  
         13'b00010001110zz : data\_tmp1 = 10'b0101101000;  
         13'b000100011110z : data\_tmp1 = 10'b0101101000;

45      13'b000100011111z : data\_tmp1 = 10'b0101101001;  
      13'b0001001000zzz : data\_tmp1 = 10'b0101101001;

50      13'b0001001001zzz : data\_tmp1 = 10'b0101101010;  
      13'b000100101000z : data\_tmp1 = 10'b0101101010;

         13'b0001001010z1z : data\_tmp1 = 10'b0101101011;  
         13'b000100101010z : data\_tmp1 = 10'b0101101011;  
         13'b00010010110zz : data\_tmp1 = 10'b0101101011;

55      13'b0001001011100 : data\_tmp1 = 10'b0101101011;

13'b00001100000zz : data\_tmp1 = 10'b0101010010;  
13'b000011000010z : data\_tmp1 = 10'b0101010010;

5   13'b000011000011z : data\_tmp1 = 10'b0101010011;  
   13'b00001100010zz : data\_tmp1 = 10'b0101010011;

10   13'b00001100011zz : data\_tmp1 = 10'b0101010100;  
   13'b000011001000z : data\_tmp1 = 10'b0101010100;  
   13'b0000110010010 : data\_tmp1 = 10'b0101010100;

15   13'b0000110010z11 : data\_tmp1 = 10'b0101010101;  
   13'b000011001010z : data\_tmp1 = 10'b0101010101;  
   13'b0000110010110 : data\_tmp1 = 10'b0101010101;  
   13'b000011001100z : data\_tmp1 = 10'b0101010101;

20   13'b0000110011010 : data\_tmp1 = 10'b0101010101;

   13'b0000110011z11 : data\_tmp1 = 10'b0101010110;  
   13'b000011001110z : data\_tmp1 = 10'b0101010110;  
   13'b0000110011110 : data\_tmp1 = 10'b0101010110;

25   20   13'b000011010000z : data\_tmp1 = 10'b0101010110;

   13'b0000110100z1z : data\_tmp1 = 10'b0101010111;  
   13'b000011010010z : data\_tmp1 = 10'b0101010111;  
   13'b0000110101000 : data\_tmp1 = 10'b0101010111;

30   25   13'b00001101010z1 : data\_tmp1 = 10'b0101011000;  
   13'b0000110101z10 : data\_tmp1 = 10'b0101011000;  
   13'b000011010110z : data\_tmp1 = 10'b0101011000;  
   13'b0000110101111 : data\_tmp1 = 10'b0101011000;

35   30   13'b0000110110000 : data\_tmp1 = 10'b0101011000;

   13'b00001101100z1 : data\_tmp1 = 10'b0101011001;  
   13'b0000110110z10 : data\_tmp1 = 10'b0101011001;  
   13'b000011011010z : data\_tmp1 = 10'b0101011001;

40   35   13'b0000110110111 : data\_tmp1 = 10'b0101011001;  
   13'b0000110111000 : data\_tmp1 = 10'b0101011001;

   13'b00001101110z1 : data\_tmp1 = 10'b0101011010;  
   13'b0000110111z10 : data\_tmp1 = 10'b0101011010;

45   40   13'b000011011110z : data\_tmp1 = 10'b0101011010;  
   13'b0000110111111 : data\_tmp1 = 10'b0101011010;

   13'b0000111000zzz : data\_tmp1 = 10'b0101011011;

50   45   13'b0000111001zzz : data\_tmp1 = 10'b0101011100;

   13'b0000111010zzz : data\_tmp1 = 10'b0101011101;  
   13'b0000111011000 : data\_tmp1 = 10'b0101011101;

55   50   13'b00001110110z1 : data\_tmp1 = 10'b0101011110;  
   13'b0000111011z10 : data\_tmp1 = 10'b0101011110;  
   13'b000011101110z : data\_tmp1 = 10'b0101011110;  
   13'b0000111011111 : data\_tmp1 = 10'b0101011110;  
   13'b0000111100000 : data\_tmp1 = 10'b0101011110;

   55   13'b00001111000z1 : data\_tmp1 = 10'b0101011111;

13'b00001001100z1 : data\_tmp1 = 10'b0101000101;  
13'b0000100110010 : data\_tmp1 = 10'b0101000101;  
13'b000010011010z : data\_tmp1 = 10'b0101000101;

5    13'b000010011011z : data\_tmp1 = 10'b0101000110;  
13'b000010011100z : data\_tmp1 = 10'b0101000110;  
13'b0000100111010 : data\_tmp1 = 10'b0101000110;

10   13'b0000100111z11 : data\_tmp1 = 10'b0101000111;  
13'b000010011110z : data\_tmp1 = 10'b0101000111;  
13'b0000100111110 : data\_tmp1 = 10'b0101000111;  
13'b0000101000000 : data\_tmp1 = 10'b0101000111;

15   13'b0000101000z1 : data\_tmp1 = 10'b0101001000;  
13'b0000101000z10 : data\_tmp1 = 10'b0101001000;  
13'b000010100010z : data\_tmp1 = 10'b0101001000;

20   13'b0000101000111 : data\_tmp1 = 10'b0101001001;  
13'b00001010010zz : data\_tmp1 = 10'b0101001001;  
13'b0000101001100 : data\_tmp1 = 10'b0101001001;

25   13'b00001010011z1 : data\_tmp1 = 10'b0101001010;  
13'b0000101001110 : data\_tmp1 = 10'b0101001010;  
13'b000010101000z : data\_tmp1 = 10'b0101001010;

30   13'b0000101010z1z : data\_tmp1 = 10'b0101001011;  
13'b000010101010z : data\_tmp1 = 10'b0101001011;

35   13'b00001010110zz : data\_tmp1 = 10'b0101001100;  
13'b000010101110z : data\_tmp1 = 10'b0101001100;  
13'b0000101011110 : data\_tmp1 = 10'b0101001100;

40   13'b0000101011111 : data\_tmp1 = 10'b0101001101;  
13'b00001011000zz : data\_tmp1 = 10'b0101001101;  
13'b0000101100100 : data\_tmp1 = 10'b0101001101;

45   13'b00001011001z1 : data\_tmp1 = 10'b0101001110;  
13'b0000101100110 : data\_tmp1 = 10'b0101001110;  
13'b000010110100z : data\_tmp1 = 10'b0101001110;  
13'b0000101101010 : data\_tmp1 = 10'b0101001110;

50   13'b0000101101z11 : data\_tmp1 = 10'b0101001111;  
13'b000010110110z : data\_tmp1 = 10'b0101001111;  
13'b0000101101110 : data\_tmp1 = 10'b0101001111;  
13'b0000101110000 : data\_tmp1 = 10'b0101001111;

55   13'b00001011100z1 : data\_tmp1 = 10'b0101010000;  
13'b0000101110z10 : data\_tmp1 = 10'b0101010000;  
13'b000010111010z : data\_tmp1 = 10'b0101010000;  
13'b0000101110111 : data\_tmp1 = 10'b0101010000;

      13'b00001011110zz : data\_tmp1 = 10'b0101010001;  
      13'b000010111110z : data\_tmp1 = 10'b0101010001;  
      13'b0000101111110 : data\_tmp1 = 10'b0101010001;

      13'b0000101111111 : data\_tmp1 = 10'b0101010010;

13'b000001110100z : data\_tmp1 = 10'b0100110101;  
13'b000001110101z : data\_tmp1 = 10'b0100110110;  
13'b000001110110z : data\_tmp1 = 10'b0100110110;

5      13'b000001110111z : data\_tmp1 = 10'b0100110111;  
      13'b000001111000z : data\_tmp1 = 10'b0100110111;

10     13'b000001111001z : data\_tmp1 = 10'b0100111000;  
      13'b000001111010z : data\_tmp1 = 10'b0100111000;  
      13'b0000011110110 : data\_tmp1 = 10'b0100111000;

15     13'b0000011110111 : data\_tmp1 = 10'b0100111001;  
      13'b000001111100z : data\_tmp1 = 10'b0100111001;  
      13'b0000011111010 : data\_tmp1 = 10'b0100111001;

20     13'b0000011111011 : data\_tmp1 = 10'b0100111010;  
      13'b000001111110z : data\_tmp1 = 10'b0100111010;  
      13'b0000011111110 : data\_tmp1 = 10'b0100111010;

25     13'b0000011111111 : data\_tmp1 = 10'b0100111011;  
      13'b00001000000zz : data\_tmp1 = 10'b0100111011;

30     13'b00001000001zz : data\_tmp1 = 10'b0100111100;  
      13'b0000100001000 : data\_tmp1 = 10'b0100111100;

35     13'b00001000010z1 : data\_tmp1 = 10'b0100111101;  
      13'b0000100001010 : data\_tmp1 = 10'b0100111101;  
      13'b0000100001100 : data\_tmp1 = 10'b0100111101;

40     13'b00001000011z1 : data\_tmp1 = 10'b0100111110;  
      13'b0000100001110 : data\_tmp1 = 10'b0100111110;  
      13'b000010001000z : data\_tmp1 = 10'b0100111110;

45     13'b000010001001z : data\_tmp1 = 10'b0100111111;  
      13'b000010001010z : data\_tmp1 = 10'b0100111111;  
      13'b0000100010110 : data\_tmp1 = 10'b0100111111;

50     13'b0000100010111 : data\_tmp1 = 10'b0101000000;  
      13'b00001000110zz : data\_tmp1 = 10'b0101000000;

55     13'b00001000111zz : data\_tmp1 = 10'b0101000001;  
      13'b0000100100000 : data\_tmp1 = 10'b0101000001;

      13'b00001001001z1 : data\_tmp1 = 10'b0101000010;  
      13'b000010010010 : data\_tmp1 = 10'b0101000010;  
      13'b000010010010z : data\_tmp1 = 10'b0101000010;

      13'b000010010011z : data\_tmp1 = 10'b0101000011;  
      13'b000010010100z : data\_tmp1 = 10'b0101000011;  
      13'b0000100101010 : data\_tmp1 = 10'b0101000011;

      13'b0000100101z11 : data\_tmp1 = 10'b0101000100;  
      13'b000010010110z : data\_tmp1 = 10'b0101000100;  
      13'b0000100101110 : data\_tmp1 = 10'b0101000100;  
      13'b0000100110000 : data\_tmp1 = 10'b0101000100;

13'b000001010100z : data\_tmp1 = 10'b0100100011;  
13'b0000010101010 : data\_tmp1 = 10'b0100100011;

5   13'b0000010101011 : data\_tmp1 = 10'b0100100100;  
   13'b000001010110z : data\_tmp1 = 10'b0100100100;

10   13'b000001010111z : data\_tmp1 = 10'b0100100101;  
   13'b0000010110000 : data\_tmp1 = 10'b0100100101;

15   13'b000001011000z1 : data\_tmp1 = 10'b0100100110;  
   13'b0000010110010 : data\_tmp1 = 10'b0100100110;

20   13'b000001011010z : data\_tmp1 = 10'b0100100111;  
   13'b0000010110110 : data\_tmp1 = 10'b0100100111;

25   13'b0000010110111 : data\_tmp1 = 10'b0100101000;  
   13'b000001011100z : data\_tmp1 = 10'b0100101000;

30   13'b000001011101z : data\_tmp1 = 10'b0100101001;  
   13'b000001011110z : data\_tmp1 = 10'b0100101001;

35   13'b000001011111z : data\_tmp1 = 10'b0100101010;  
   13'b0000011000000 : data\_tmp1 = 10'b0100101010;

40   13'b000001100000z1 : data\_tmp1 = 10'b0100101011;  
   13'b0000011000010 : data\_tmp1 = 10'b0100101011;

45   13'b00000110001zz : data\_tmp1 = 10'b0100101100;

50   13'b000001100100z : data\_tmp1 = 10'b0100101101;  
   13'b0000011001010 : data\_tmp1 = 10'b0100101101;

55   13'b000001100111z : data\_tmp1 = 10'b0100101110;  
   13'b0000011001110 : data\_tmp1 = 10'b0100101110;

   13'b000001101000z : data\_tmp1 = 10'b0100110000;  
   13'b000001101010z : data\_tmp1 = 10'b0100110000;

   13'b000001101011z : data\_tmp1 = 10'b0100110001;  
   13'b000001101100z : data\_tmp1 = 10'b0100110001;

   13'b000001101101z : data\_tmp1 = 10'b0100110010;  
   13'b000001101110z : data\_tmp1 = 10'b0100110010;

   13'b000001101111z : data\_tmp1 = 10'b0100110011;  
   13'b000001110000z : data\_tmp1 = 10'b0100110011;

   13'b000001110001z : data\_tmp1 = 10'b0100110100;  
   13'b000001110010z : data\_tmp1 = 10'b0100110100;

   13'b000001110011z : data\_tmp1 = 10'b0100110101;

13'b000000111010z : data\_tmp1 = 10'b0100001110;  
13'b000000111011z : data\_tmp1 = 10'b0100001111;  
5 13'b000000111100z : data\_tmp1 = 10'b0100010000;  
13'b000000111101z : data\_tmp1 = 10'b0100010001;  
13'b000000111110z : data\_tmp1 = 10'b0100010010;  
10 13'b000000111110 : data\_tmp1 = 10'b0100010010;  
13'b000000111111 : data\_tmp1 = 10'b0100010011;  
13'b0000010000000 : data\_tmp1 = 10'b0100010011;  
15 13'b0000010000001 : data\_tmp1 = 10'b0100010100;  
13'b0000010000010 : data\_tmp1 = 10'b0100010100;  
13'b0000010000011 : data\_tmp1 = 10'b0100010101;  
13'b0000010000100 : data\_tmp1 = 10'b0100010101;  
20 13'b00000100001z1 : data\_tmp1 = 10'b0100010110;  
13'b0000010000110 : data\_tmp1 = 10'b0100010110;  
13'b000001000100z : data\_tmp1 = 10'b0100010111;  
25 13'b000001000101z : data\_tmp1 = 10'b0100011000;  
13'b0000010001100 : data\_tmp1 = 10'b0100011000;  
13'b0000010001101 : data\_tmp1 = 10'b0100011001;  
30 13'b0000010001110 : data\_tmp1 = 10'b0100011001;  
13'b0000010001111 : data\_tmp1 = 10'b0100011010;  
13'b000001001000z : data\_tmp1 = 10'b0100011010;  
35 13'b000001001001z : data\_tmp1 = 10'b0100011011;  
13'b000001001010z : data\_tmp1 = 10'b0100011100;  
13'b0000010010110 : data\_tmp1 = 10'b0100011100;  
40 13'b0000010010111 : data\_tmp1 = 10'b0100011101;  
13'b000001001100z : data\_tmp1 = 10'b0100011101;  
13'b000001001101z : data\_tmp1 = 10'b0100011110;  
45 13'b000001001110z : data\_tmp1 = 10'b0100011111;  
13'b0000010011110 : data\_tmp1 = 10'b0100011111;  
13'b0000010011111 : data\_tmp1 = 10'b0100100000;  
50 13'b000001010000z : data\_tmp1 = 10'b0100100000;  
13'b000001010001z : data\_tmp1 = 10'b0100100001;  
13'b0000010100100 : data\_tmp1 = 10'b0100100001;  
55 13'b00000101001z1 : data\_tmp1 = 10'b0100100010;  
13'b0000010100110 : data\_tmp1 = 10'b0100100010;

13'b00000001 : data\_tmp1 = 10'b0011110100;  
13'b0000001001011 : data\_tmp1 = 10'b0011110101;  
5 13'b000000100110z : data\_tmp1 = 10'b0011110110;  
13'b0000001001110 : data\_tmp1 = 10'b0011110111;  
10 13'b0000001001111 : data\_tmp1 = 10'b0011111000;  
13'b000000101000z : data\_tmp1 = 10'b0011111001;  
13'b0000001010010 : data\_tmp1 = 10'b0011111010;  
15 13'b0000001010011 : data\_tmp1 = 10'b0011111011;  
13'b0000001010100 : data\_tmp1 = 10'b0011111011;  
13'b0000001010101 : data\_tmp1 = 10'b0011111100;  
20 13'b000000101011z : data\_tmp1 = 10'b0011111101;  
13'b0000001011000 : data\_tmp1 = 10'b0011111110;  
13'b0000001011001 : data\_tmp1 = 10'b0011111111;  
25 13'b0000001011010 : data\_tmp1 = 10'b0011111111;  
13'b0000001011011 : data\_tmp1 = 10'b0100000000;  
13'b000000101110z : data\_tmp1 = 10'b0100000001;  
30 13'b000000101111z : data\_tmp1 = 10'b0100000010;  
13'b0000001100000 : data\_tmp1 = 10'b0100000011;  
35 13'b0000001100001 : data\_tmp1 = 10'b0100000100;  
13'b0000001100010 : data\_tmp1 = 10'b0100000100;  
13'b0000001100011 : data\_tmp1 = 10'b0100000101;  
40 13'b0000001100100 : data\_tmp1 = 10'b0100000101;  
13'b0000001100101 : data\_tmp1 = 10'b0100000110;  
13'b0000001100110 : data\_tmp1 = 10'b0100000110;  
45 13'b0000001100111 : data\_tmp1 = 10'b0100000111;  
13'b000000110100z : data\_tmp1 = 10'b0100001000;  
13'b000000110101z : data\_tmp1 = 10'b0100001001;  
50 13'b000000110110z : data\_tmp1 = 10'b0100001010;  
13'b000000110111z : data\_tmp1 = 10'b0100001011;  
13'b000000111000z : data\_tmp1 = 10'b0100001100;  
55 13'b000000111001z : data\_tmp1 = 10'b0100001101;

13'b0000000101100 : data\_tmp1 = 10'b0011010111;  
13'b0000000101101 : data\_tmp1 = 10'b0011011000;  
5 13'b0000000101110 : data\_tmp1 = 10'b0011011001;  
13'b0000000101111 : data\_tmp1 = 10'b0011011010;  
10 13'b0000000110000 : data\_tmp1 = 10'b0011011100;  
13'b0000000110001 : data\_tmp1 = 10'b0011011101;  
13'b0000000110010 : data\_tmp1 = 10'b0011011110;  
15 13'b0000000110011 : data\_tmp1 = 10'b0011011111;  
13'b0000000110100 : data\_tmp1 = 10'b0011100000;  
13'b0000000110101 : data\_tmp1 = 10'b0011100001;  
20 13'b0000000110110 : data\_tmp1 = 10'b0011100010;  
13'b0000000110111 : data\_tmp1 = 10'b0011100011;  
25 13'b0000000111000 : data\_tmp1 = 10'b0011100100;  
13'b0000000111001 : data\_tmp1 = 10'b0011100101;  
13'b0000000111010 : data\_tmp1 = 10'b0011100110;  
30 13'b0000000111011 : data\_tmp1 = 10'b0011100111;  
13'b0000000111100 : data\_tmp1 = 10'b0011101000;  
35 13'b0000000111101 : data\_tmp1 = 10'b0011101001;  
13'b0000000111110 : data\_tmp1 = 10'b0011101010;  
13'b0000000111111 : data\_tmp1 = 10'b0011101011;  
40 13'b0000001000000 : data\_tmp1 = 10'b0011101100;  
13'b0000001000001 : data\_tmp1 = 10'b0011101101;  
45 13'b0000001000010 : data\_tmp1 = 10'b0011101110;  
13'b0000001000011 : data\_tmp1 = 10'b0011101111;  
13'b0000001000100 : data\_tmp1 = 10'b0011101111;  
50 13'b0000001000101 : data\_tmp1 = 10'b0011110000;  
13'b0000001000110 : data\_tmp1 = 10'b0011110001;  
13'b0000001000111 : data\_tmp1 = 10'b0011110010;  
55 13'b000000100100z : data\_tmp1 = 10'b0011110011;

13'b0000000010000 : data\_tmp1 = 10'b0010011101;  
13'b0000000010001 : data\_tmp1 = 10'b0010100001;  
5 13'b0000000010010 : data\_tmp1 = 10'b0010100100;  
13'b0000000010011 : data\_tmp1 = 10'b0010100111;  
10 13'b0000000010100 : data\_tmp1 = 10'b0010101010;  
13'b0000000010101 : data\_tmp1 = 10'b0010101101;  
13'b0000000010110 : data\_tmp1 = 10'b0010101111;  
15 13'b0000000010111 : data\_tmp1 = 10'b0010110010;  
13'b0000000011000 : data\_tmp1 = 10'b0010110100;  
20 13'b0000000011001 : data\_tmp1 = 10'b0010110111;  
13'b0000000011010 : data\_tmp1 = 10'b0010111001;  
13'b0000000011011 : data\_tmp1 = 10'b0010111011;  
25 13'b0000000011100 : data\_tmp1 = 10'b0010111101;  
13'b0000000011101 : data\_tmp1 = 10'b0010111111;  
30 13'b0000000011110 : data\_tmp1 = 10'b0011000001;  
13'b0000000011111 : data\_tmp1 = 10'b0011000011;  
13'b00000000100000 : data\_tmp1 = 10'b0011000101;  
35 13'b00000000100001 : data\_tmp1 = 10'b0011000110;  
13'b00000000100010 : data\_tmp1 = 10'b0011001000;  
40 13'b00000000100011 : data\_tmp1 = 10'b0011001010;  
13'b00000000100100 : data\_tmp1 = 10'b0011001011;  
13'b00000000100101 : data\_tmp1 = 10'b0011001101;  
45 13'b00000000100110 : data\_tmp1 = 10'b0011001110;  
13'b00000000100111 : data\_tmp1 = 10'b0011010000;  
50 13'b00000000101000 : data\_tmp1 = 10'b0011010001;  
13'b00000000101001 : data\_tmp1 = 10'b0011010011;  
13'b00000000101010 : data\_tmp1 = 10'b0011010100;  
55 13'b00000000101011 : data\_tmp1 = 10'b0011010101;

variance of the data and hence the F\_ratio.

Notes :

5

\*\*\*\*\*`timescale 1ns / 100ps

```
module fft_window_lu (clk, enable_3, in_address, out_data);
parameter      r_wordlength = 10; // Data wordlength.
parameter      lu_AddressSize = 13; // Address bus size.

input          clk,
              enable_3;
input [lu_AddressSize-1:0] in_address;
output [r_wordlength-1:0] out_data;

reg [r_wordlength-1:0] data_tmp1,
                      data_tmp2;

always @(in_address)
casez (in_address)
 13'b0000000000000 : data_tmp1 = 10'b1000000000;
 13'b0000000000001 : data_tmp1 = 10'b0000000000;
 13'b0000000000010 : data_tmp1 = 10'b0000100111;
 13'b0000000000011 : data_tmp1 = 10'b0000111110;
 13'b0000000000100 : data_tmp1 = 10'b0001001110;
 13'b0000000000101 : data_tmp1 = 10'b0001011011;
 13'b0000000000110 : data_tmp1 = 10'b0001100110;
 13'b0000000000111 : data_tmp1 = 10'b0001101110;
 13'b0000000001000 : data_tmp1 = 10'b0001110110;
 13'b0000000001001 : data_tmp1 = 10'b0001111101;
 13'b0000000001010 : data_tmp1 = 10'b0010000011;
 13'b0000000001011 : data_tmp1 = 10'b0010001000;
 13'b0000000001100 : data_tmp1 = 10'b0010001101;
 13'b0000000001101 : data_tmp1 = 10'b0010010001;
 13'b0000000001110 : data_tmp1 = 10'b0010010110;
 13'b0000000001111 : data_tmp1 = 10'b0010011010;
```

```

       .ovf_10 || ovf_11 || ovf_12 || ovf_13 || ovf_14 ||
       ovf_15;

// 2k/8k Overflow flag configuration.
5   always @(in_2k8k or ovf_16 or ovf_17 or ovf_18 or ovf_2k)
    if (in_2k8k)
        ovf_tmp1 = ovf_2k || ovf_16 || ovf_17 || ovf_18;
    else
        ovf_tmp1 = ovf_2k;
10
10  always @ (posedge clk)           // Register overflow
    if (enable_3 && fft_cycle_complete) // flag to change when
        ovf_tmp2 <= ovf_tmp1;          // I/Q samples are valid
                                // from FFT processor.
15  assign out_ovf = ovf_tmp2;

`ifdef OVERFLOW_DEBUG
// Debug code to display overflow output of a particular instance.
// Concurrently monitor overflow flag and halt on overflow.
20  always @ (out_ovf) // ovf_x wires are all registered at lower level.
    if (out_ovf)
        begin
            $display ("Overflow has occurred, type . to continue.");
            $display ("Overflow flag, out_ovf = ",out_ovf);
25
25  if (ovf_18) $display ("Overflow on port ovf_18");
    if (ovf_17) $display ("Overflow on port ovf_17");
    if (ovf_16) $display ("Overflow on port ovf_16");
    if (ovf_15) $display ("Overflow on port ovf_15");
    if (ovf_14) $display ("Overflow on port ovf_14");
30
30  if (ovf_13) $display ("Overflow on port ovf_13");
    if (ovf_12) $display ("Overflow on port ovf_12");
    if (ovf_11) $display ("Overflow on port ovf_11");
    if (ovf_10) $display ("Overflow on port ovf_10");
    if (ovf_9) $display ("Overflow on port ovf_9");
35
35  if (ovf_8) $display ("Overflow on port ovf_8");
    if (ovf_7) $display ("Overflow on port ovf_7");
    if (ovf_6) $display ("Overflow on port ovf_6");
    if (ovf_5) $display ("Overflow on port ovf_5");
    if (ovf_4) $display ("Overflow on port ovf_4");
40
40  if (ovf_3) $display ("Overflow on port ovf_3");
    if (ovf_2) $display ("Overflow on port ovf_2");
    if (ovf_1) $display ("Overflow on port ovf_1");
    if (ovf_0) $display ("Overflow on port ovf_0");
    $stop;
45
45  end
`endif
endmodule

```

Listing 13

50 // SccsId: %W% %G%

\*\*\*\*\*

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55

Description: Verilog code for the window lookup table, used to determine the

```

t <= t + 1'b1;

assign ram_address = t;

5 assign ram_enable = enable_3 || enable_2; // ram enable signal.
// -----
// valid_out status flag generation.
// -----


10 always @(posedge clk)
if (!nrst)
fft_cycle_complete <= 1'b0; // Detect end of 1st fft cycle i.e. 2K or 8K.
else if ((~in_2k8k && &address[10:0]) || (in_2k8k && &address[12:0]))
fft_cycle_complete <= 1'b1;
15 else
fft_cycle_complete <= fft_cycle_complete;

always @(posedge clk) // Account for pipeline and I/O registers.
if (!nrst)
20 pipeline_count <= 4'b0; // Stop at pipeline_depth - 1.
else if (enable_3 && fft_cycle_complete & pipeline_count < 8)//pipe depth=8
pipeline_count <= pipeline_count + 1'b1;

always @(posedge clk) // Test if the pipeline is full and the input
25 if (!nrst) // is valid before asserting valid_out.
output_valid <= 1'b0;
else if (enable_2 && pipeline_count[3])
output_valid <= 1'b1;
else
30 output_valid <= 1'b0;

assign valid_out = output_valid;

// -----
35 // Fast 40 MHz clock decoder and valid_in control.
// -----


always @(posedge clk)
if (!nrst) // Synchronous power-up reset.
40 r <= 0;
else if (valid_in) // Count if input data valid.
r <= r + 1'b1;

assign control = {valid_in & r[1],valid_in & r[0]};

45 assign enable_0 = valid_in & (~r[1] & ~r[0]); // Gate valid_in with
assign enable_1 = valid_in & (~r[1] & r[0]); // decoded enable signals
assign enable_2 = valid_in & ( r[1] & ~r[0]); // to control all reg's.
assign enable_3 = valid_in & ( r[1] & r[0]);
50
// -----
// Overflow detection, OR overflows from each stage to give overflow flag.
// -----


55 assign ovf_2k = ovf_0 || ovf_1 || ovf_2 || ovf_3 || ovf_4 ||
ovf_5 || ovf_6 || ovf_7 || ovf_8 || ovf_9 ||
```

```

assign out_xr = xr_tmp2;
assign out_xi = xi_tmp2;

5   always @(posedge clk)      // RAMs are latched on outputs so no
begin          // need to enable.
    z2r_4 <= z2r_4_tmp;    // Register FFT outputs to RAM.
    z2i_4 <= z2i_4_tmp;
    z2r_5 <= z2r_5_tmp;
    z2i_5 <= z2i_5_tmp;
10   z2r_6 <= z2r_6_tmp;
    z2i_6 <= z2i_6_tmp;
    z2r_7 <= z2r_7_tmp;
    z2i_7 <= z2i_7_tmp;
    z2r_8 <= z2r_8_tmp;
    z2i_8 <= z2i_8_tmp;
15   z2r_9 <= z2r_9_tmp;
    z2i_9 <= z2i_9_tmp;
    // z2r_10 <= z2r_10_tmp;
    // z2i_10 <= z2i_10_tmp;
20   x1r_4_tmp <= x1r_4;    // Register FFT inputs from RAM.
    x1i_4_tmp <= x1i_4;
    x1r_5_tmp <= x1r_5;
    x1i_5_tmp <= x1i_5;
    x1r_6_tmp <= x1r_6;
25   x1i_6_tmp <= x1i_6;
    x1r_7_tmp <= x1r_7;
    x1i_7_tmp <= x1i_7;
    x1r_8_tmp <= x1r_8;
    x1i_8_tmp <= x1i_8;
30   x1r_9_tmp <= x1r_9;
    x1i_9_tmp <= x1i_9;
    // x1r_10_tmp <= x1r_10;
    // x1i_10_tmp <= x1i_10;
    end
35

// -----
//      Synchronous butterfly controller.
// -----
40   always @(posedge clk)
if (!nrst)           // Synchronous power-up reset.
    q <= 0;
else if (enable_3)
    q <= q + 1'b1;

45   assign address = q;

// -----
//      Synchronous RAM address generator.
// -----
50   always @(posedge clk)
if (!nrst)           // Synchronous power-up reset.
    t <= 0;
else if (enable_2)

```

```

    ovf_1);

fft_bf2l #(wordlength) bf2l_0 (clk, enable_1,
    x1r_0, x1i_0,           // Inputs.
    x2r_0, x2i_0,
5      s[0],
    xr_tmp1, xi_tmp1,      // Outputs.
    z2r_0, z2i_0,
    ovf_0);

10     assign s[0] = ~address[0]; // Invert s[0] (see count sequence), SR0 not req.
//fft_sr_1bit #(7) sr_1bit_0 (clk, enable_3, address[0], s[0]); // SR 0.

15     // Last stage should be just a single register as only 1 location needed.
always @ (posedge clk) // No reset required as data clocked through registers.
if (enable_3)
begin
    x1r_0_reg <= z2r_0;
    x1i_0_reg <= z2i_0;
20
end
    |
assign x1r_0 = x1r_0_reg;
assign x1i_0 = x1i_0_reg;

25     // -----
// Register Inputs/Outputs.
// -----
`ifndef BIN_SHIFT
30     always @ (posedge clk) // Registered inputs.
if (enable_3 && !address[0]) // == freq bin shift by pi.
begin
    xr_reg <= in_xr;
    xi_reg <= in_xi;
35
end
else if (enable_3 && address[0]) // == freq bin shift by pi.
begin
    xr_reg <= ~in_xr + 1'b1; // This is equivalent to multiplying by
    xi_reg <= ~in_xi + 1'b1; // exp(-j * pi * n) == (-1)^n.
40
end
`else
always @ (posedge clk) // Registered inputs.
if (enable_3)
begin
45     xr_reg <= in_xr;
    xi_reg <= in_xi;
end
`endif
50     always @ (posedge clk) // Registered outputs.
if (enable_3)
begin
    xr_tmp2 <= xr_tmp1;
    xi_tmp2 <= xi_tmp1;
55
end

```

```

      z2r_3, z2i_3,
      ovf_5);

5   fft_sr_1bit #(5) sr_1bit_3 (clk, enable_3, address[3], s[3]); // SR 3.
      fft_sr_1bit #(5) sr_1bit_4 (clk, enable_3, address[4], s[4]); // SR 4.

     fft_sr_iq #(wordlength, 8) sr_iq_3 (clk, enable_3,    // Length = 8.
           z2r_3, z2i_3,          // Inputs.
           x1r_3, x1i_3);        // Outputs.

10
// -----
//       Section 2 and 1.
// -----
15   fft_complex_mult_mux #(wordlength, c_wordlength, mult_scale) m1
      (clk, control,
       ar_1, ai_1, br_1, bi_1,      // Inputs.
       x2r_2, x2i_2,              // Outputs.
       ovf_4);

20   fft_bf2l #(wordlength) bf2l_1 (clk, enable_1,
      x1r_2, x1i_2,            // Inputs.
      x2r_2, x2i_2,
      s[2],
      x2r_1, x2i_1,            // Outputs.
      z2r_2, z2i_2,
      ovf_3);

25   fft_sr_iq #(wordlength, 4) sr_iq_2 (clk, enable_3,    // Length = 4.
      z2r_2, z2i_2,            // Inputs.
      x1r_2, x1i_2);          // Outputs.

30   fft_bf2ll #(wordlength) bf2ll_1 (clk, enable_1,
      x1r_1, x1i_1,            // Inputs.
      x2r_1, x2i_1,
      s[1], s[2],
      ar_0, ai_0,              // Outputs.
      z2r_1, z2i_1,
      ovf_2);

35
40   assign s[1] = ~address[1]; // Invert s[1] (see count sequence), SR1 not req.
//fft_sr_1bit #(6) sr_1bit_1 (clk, enable_3, address[1], s[1]); // SR 1.
//fft_sr_1bit #(6) sr_1bit_2 (clk, enable_3, address[2], s[2]); // SR 2.

45   fft_sr_iq #(wordlength, 2) sr_iq_1 (clk, enable_3,    // Length = 2.
      z2r_1, z2i_1,            // Inputs.
      x1r_1, x1i_1);          // Outputs.

50
// -----
//       Section 0, front end of FFT pipeline (output stage), mult_scale=4.
// -----
55   fft_complex_mult_mux #(wordlength, c_wordlength, 4) m0
      (clk, control,
       ar_0, ai_0, br_0, bi_0,      // Inputs.
       x2r_0, x2i_0,              // Outputs.

```

```
fft_sr_1bit #(3) sr_1bit_7 (clk, enable_3, address[7], s[7]); // SR 7.  
fft_sr_1bit #(3) sr_1bit_8 (clk, enable_3, address[8], s[8]); // SR 8.  
5 // -----  
// Section 6 and 5.  
// -----  
10 fft_complex_mult_mux #(wordlength, c_wordlength, mult_scale) m3  
    (clk, control,  
     ar_3, ai_3, br_3, bi_3,      // Inputs.  
     x2r_6, x2i_6,              // Outputs.  
     ovf_10);  
15 fft_bf2l #(wordlength) bf2l_3 (clk, enable_1,  
    x1r_6_tmp, x1i_6_tmp,    // inputs.  
    x2r_6, x2i_6,  
    s[6],  
    x2r_5, x2i_5,      // Outputs.  
20    z2r_6_tmp, z2i_6_tmp,  
    ovf_9);  
25 fft_bf2ll #(wordlength) bf2ll_3 (clk, enable_1,  
    x1r_5_tmp, x1i_5_tmp,    // Inputs.  
    x2r_5, x2i_5,  
    s[5], s[6],  
    ar_2, ai_2,      // Outputs.  
    z2r_5_tmp, z2i_5_tmp,  
    ovf_8);  
30 fft_sr_1bit #(4) sr_1bit_5 (clk, enable_3, address[5], s[5]); // SR 5.  
fft_sr_1bit #(4) sr_1bit_6 (clk, enable_3, address[6], s[6]); // SR 6.  
35 // -----  
// Section 4 and 3.  
// -----  
40 fft_complex_mult_mux #(wordlength, c_wordlength, mult_scale) m2  
    (clk, control,  
     ar_2, ai_2, br_2, bi_2,      // Inputs.  
     x2r_4, x2i_4,              // Outputs.  
     ovf_7);  
45 fft_bf2l #(wordlength) bf2l_2 (clk, enable_1,  
    x1r_4_tmp, x1i_4_tmp,    // Inputs.  
    x2r_4, x2i_4,  
    s[4],  
    x2r_3, x2i_3,      // Outputs.  
    z2r_4_tmp, z2i_4_tmp,  
50    ovf_6);  
55 fft_bf2ll #(wordlength) bf2ll_2 (clk, enable_1,  
    x1r_3, x1i_3,    // Inputs.  
    x2r_3, x2i_3,  
    s[3], s[4],  
    ar_1, ai_1,      // Outputs.
```

```

// -----
//      Section 10 and 9.
// -----
5    fft_complex_mult_mux #(wordlength, c_wordlength, mult_scale) m5
        (clk, control,
         ar_5, ai_5, br_5, bi_5,      // Inputs.
         x2r_10_tmp1, x2i_10_tmp1,   // Outputs.
10       ovf_16);

fft_bf2l #(wordlength) bf2l_5 (clk, enable_1,
        x1r_10, x1i_10      // Inputs.
        x2r_10, x2i_10,
15       s[10],
        x2r_9, x2i_9,      // Outputs.
        z2r_10, z2i_10,
        ovf_15);

20    fft_bf2ll #(wordlength) bf2ll_5 (clk, enable_1,
        x1r_9_tmp, x1i_9_tmp, // Inputs.
        x2r_9, x2i_9,
        s[9], s[10],
        ar_4, ai_4,      // Outputs.
25       z2r_9_tmp, z2i_9_tmp,
        ovf_14);

fft_sr_1bit #(2) sr_1bit_9 (clk, enable_3, address[9], s[9]); // SR 9.
fft_sr_1bit #(2) sr_1bit_10 (clk, enable_3, address[10], s[10]); // SR 10.
30

// -----
//      Section 8 and 7.
// -----
35    fft_complex_mult_mux #(wordlength, c_wordlength, mult_scale) m4
        (clk, control,
         ar_4, ai_4, br_4, bi_4,      // Inputs.
         x2r_8, x2i_8,      // Outputs.
40       ovf_13);

fft_bf2l #(wordlength) bf2l_4 (clk, enable_1,
        x1r_8_tmp, x1i_8_tmp, // Inputs.
        x2r_8, x2i_8,
45       s[8],
        x2r_7, x2i_7,      // Outputs.
        z2r_8_tmp, z2i_8_tmp,
        ovf_12);

50    fft_bf2ll #(wordlength) bf2ll_4 (clk, enable_1,
        x1r_7_tmp, x1i_7_tmp, // Inputs.
        x2r_7, x2i_7,
        s[7], s[8],
        ar_3, ai_3,      // Outputs.
55       z2r_7_tmp, z2i_7_tmp,
        ovf_11);

```

```

begin
  x2r_10_tmp2 = x2r_10_tmp1;
  x2i_10_tmp2 = x2i_10_tmp1;
  // Sign extend from 10 bits, as section 12 is s12_wdlength bits.
  5   in_xr_tmp = {{{(s12_wdlength-9){xr_reg[9]}},xr_reg[8:0]}};
      in_xi_tmp = {{{(s12_wdlength-9){xi_reg[9]}},xi_reg[8:0]}};
end

10 always @(posedge clk) // Pipeline register to enable correct operation in
if (enable_3) // 2K mode without retiming the entire pipeline since
begin // 8K mode introduces 1 additional pipeline register.
  // Sign extend 10 bit inputs to wordlength bit inputs.
  // for bypass lines into stage 5.
  15 x2r_10_tmp3 <= {{{(wordlength-9){xr_reg[9]}},xr_reg[8:0]}};
      x2i_10_tmp3 <= {{{(wordlength-9){xi_reg[9]}},xi_reg[8:0]}};
end

20 assign x2r_10 = x2r_10_tmp2;
assign x2i_10 = x2i_10_tmp2;

// Sign extend from s12_wdlength bits to s11_wdlength bits between
// sections 12 and 11. Uncomment below if s_11 < > s_12.
25 assign x2r_11 = {{{(s11_wdlength-s12_wdlength+1)
  {x2r_11_tmp[s12_wdlength-1]}},x2r_11_tmp[s12_wdlength-2:0]}};
assign x2i_11 = {{{(s11_wdlength-s12_wdlength+1)
  {x2i_11_tmp[s12_wdlength-1]}},x2i_11_tmp[s12_wdlength-2:0]}};

// Uncomment below if s_11 = s_12.
/* assign x2r_11 = x2r_11_tmp;
assign x2i_11 = x2i_11_tmp; */

30 fft_bf2I #(s12_wdlength) bf2I_6
  (clk, enable_1,
   x1r_12, x1i_12, in_xr_tmp, in_xi_tmp, // Ext In.
   s[12],
35   x2r_11_tmp, x2i_11_tmp, z2r_12, z2i_12, // Outputs.
   ovf_18);

/* fft_ram #(s12_wdlength, 12) ram_12 (clk, enable_1, enable_3,
   ram_address[11:0], // 4096 addrs.
40   z2r_12, z2i_12, // Inputs.
   x1r_12, x1i_12); // Outputs. */

fft_bf2II #(s11_wdlength) bf2II_6
  (clk, enable_1,
   x1r_11, x1i_11, x2r_11, x2i_11, // Inputs.
   s[11], s[12],
45   ar_5, ai_5, z2r_11, z2i_11, // Outputs.
   ovf_17);

50 fft_sr_1bit #(1) sr_1bit_11 (clk, enable_3, address[11], s[11]); // SR 11.
fft_sr_1bit #(1) sr_1bit_12 (clk, enable_3, address[12], s[12]); // SR 12.

/* fft_ram #(s11_wdlength, 11) ram_11 (clk, enable_1, enable_3,
   ram_address[10:0], // 2048 addrs.
55   z2r_11, z2i_11, // Inputs.
   x1r_11, x1i_11); // Outputs. */

```

```

fft_hardwired_lu2 #(c_wordlength, rom_AddressSize-0) // Case table instance
rom2 (clk, enable_3, address[6:0], br_2, bi_2); // for a hardwired ROM.

5 /*fft_hardwired_lu3 #(c_wordlength, rom_AddressSize-4) // Case table instance
rom3 (clk, enable_3, address[8:0], br_3, bi_3); // for a hardwired ROM.*/
/*fft_hardwired_lu3 #(c_wordlength, rom_AddressSize-5)// Case table instance
rom3 (clk, enable_3, address_rom3, br_3, bi_3); // for a hardwired ROM.*/
10 /*fft_rom #(c_wordlength, rom_AddressSize-6,
  ".//fft/src/lookup_tables/lu_10bit_128pt_scale1")
rom2 (address[6:0], br_2, bi_2); // 128 addresses x 20 bits, no decode. */
/*fft_rom #(c_wordlength, rom_AddressSize-7,
  ".//fft/src/lookup_tables/lu_10bit_128pt_scale1")
rom2 (address_rom2, br_2, bi_2); // 64 addresses x 20 bits, coeff decode. */
15 /*fft_rom #(c_wordlength, rom_AddressSize-4,
  ".//fft/src/lookup_tables/lu_10bit_512pt_scale1")
rom3 (address[8:0], br_3, bi_3); // 512 addresses x 20 bits, no decode. */
/* fft_rom #(c_wordlength, rom_AddressSize-5,
  ".//fft/src/lookup_tables/lu_10bit_512pt_scale1")
rom3 (clk, enable_3, address_rom3, br_3, bi_3); // 256 addresses x 20 bits.*/
20 /*fft_rom #(c_wordlength, rom_AddressSize-2,
  ".//fft/src/lookup_tables/lu_10bit_2048pt_scale1")
rom4 (address[10:0], br_4, bi_4); // 2048 addresses x 20 bits, no decode. */
25 /* fft_rom #(c_wordlength, rom_AddressSize-3,
  ".//fft/src/lookup_tables/lu_10bit_2048pt_scale1")
rom4 (clk, enable_3, address_rom4, br_4, bi_4); // 1024 addresses x 20 bits.*/
30 /*fft_rom #(c_wordlength, rom_AddressSize-1,
  ".//fft/src/lookup_tables/lu_10bit_8192pt_scale1")
rom5 (address, br_5, bi_5); // 8192 addresses x 20 bits, no decode. */
35 /* fft_rom #(c_wordlength, rom_AddressSize-1,
  ".//fft/src/lookup_tables/lu_10bit_8192pt_scale1")
rom5 (clk, enable_3, address_rom5, br_5, bi_5); // 4096 addresses x 20 bits.*/
40 // -----
// Section 12 and 11, tail end of FFT pipeline (input stage).
// Section 12 is 11 bits wide and incorporates the 2K/8K control logic.
45 // -----
always @ (xr_reg or xi_reg or in_2k8k or x2r_10_tmp1 or x2i_10_tmp1
      or x2r_10_tmp3 or x2i_10_tmp3)
if (!in_2k8k) // Configuring for 2K mode.
50 begin
  x2r_10_tmp2 = x2r_10_tmp3;
  x2i_10_tmp2 = x2i_10_tmp3;
  in_xr_tmp = 0;
  in_xi_tmp = 0;
55 end
else // Configuring for 8K mode.

```

```

reg [9:0] xr_reg, // Input data reg, I.
           xi_reg; // Input data reg, Q.
reg [wordlength-1:0] x2r_10_tmp2, x2i_10_tmp2,
                     x2r_10_tmp3, x2i_10_tmp3;
5
wire [wordlength-1:0] xr_tmp1, // Final BF2I(0) out, I.
                     xi_tmp1; // Final BF2I(0) out, Q.
wire [wordlength-1:0] x2r_10_tmp1, x2i_10_tmp1;
wire [s12_wdlength-1:0] x2r_11_tmp, x2i_11_tmp;
10
// -----
// Address decoders/Quadrant mappers + pipeline shift registers.
// ----

15 /* fft_sr_addr #(rom_AddressSize-6, 3) sr_addr_2
      (clk, enable_3,
       address[6:0], // Input.
       dcd_address2); // Output.

20 fft_coeff_dcd #(rom_AddressSize-6, 11, 21)
coeff_dcd_2 (clk, enable_3, dcd_address2, address_rom2, nrst); */

// ----

25 fft_sr_addr #(rom_AddressSize-4, 2) sr_addr_3
      (clk, enable_3,
       address[8:0], // Input.
       dcd_address3); // Output.

30 fft_coeff_dcd #(rom_AddressSize-4, 43, 85)
coeff_dcd_3 (clk, enable_3, dcd_address3, address_rom3, nrst);

// ----

35 fft_sr_addr #(rom_AddressSize-2, 1) sr_addr_4
      (clk, enable_3,
       address[10:0], // Input.
       dcd_address4); // Output.

40 fft_coeff_dcd #(rom_AddressSize-2, 171, 341)
coeff_dcd_4 (clk, enable_3, dcd_address4, address_rom4, nrst);

// ----

45 /* fft_coeff_dcd #(rom_AddressSize, 683, 1365)
coeff_dcd_5 (clk, enable_3, address, address_rom5, nrst); */

// -----
// ROM lookup tables.
50 // -----
fft_hardwired_lu0 #(c_wordlength, rom_AddressSize-10)// Case table instance
rom0 (clk, enable_3, address[2:0], br_0, bi_0); // for a hardwired ROM.

55 fft_hardwired_lu1 #(c_wordlength, rom_AddressSize-8) // Case table instance
rom1 (clk, enable_3, address[4:0], br_1, bi_1); // for a hardwired ROM.

```

```

wire [wordlength-1:0] z2r_10, z2i_10; // WILL CHANGE WHEN RAM RIGHT 2 rg
wire [wordlength-1:0] z2r_4_tmp, z2i_4_tmp, // Couple the I/Q data
5      z2r_5_tmp, z2i_5_tmp, // outputs of each BF
      z2r_6_tmp, z2i_6_tmp, // processor to their
      z2r_7_tmp, z2i_7_tmp, // respective memory
      z2r_8_tmp, z2i_8_tmp, // inputs via an output
      z2r_9_tmp, z2i_9_tmp, // register.
      z2r_10_tmp, z2i_10_tmp;
10
wire [s11_wdlength-1:0] z2r_11, z2i_11; // Different bit-widths
wire [s12_wdlength-1:0] z2r_12, z2i_12; // for the 1st 2 stages.

15 wire [rom_AddressSize-8:0] address_rom2; // Couples the address
wire [rom_AddressSize-6:0] address_rom3; // decoders outputs to
wire [rom_AddressSize-4:0] address_rom4; // respective ROMs.
wire [rom_AddressSize-2:0] address_rom5;

20 wire [rom_AddressSize-7:0] dcd_address2; // Couples part of the
wire [rom_AddressSize-5:0] dcd_address3; // address bus to the
wire [rom_AddressSize-3:0] dcd_address4; // coefficient decoder.
wire [rom_AddressSize-1:0] dcd_address5;

25 wire      ovf_0, ovf_1,    // Couples overflow
      ovf_2, ovf_3,    // flag outputs from
      ovf_4, ovf_5,    // each butterfly
      ovf_6, ovf_7,    // processor and complex
      ovf_8, ovf_9,    // multiplier into one
      ovf_10, ovf_11,   // overflow status flag
      ovf_12, ovf_13,   // called "out_ovf".
      ovf_14, ovf_15,
      ovf_16, ovf_17,
      ovf_18;

30
35 wire      clk,
      nrst,
      in_2k8k,
      ovf_2k,
      out_ovf,
      enable_0,
      enable_1,
      enable_2,
      enable_3,
      ram_enable; // RAM enable signal.

40
45 reg      ovf_tmp1,
      ovf_tmp2,
      fft_cycle_complete, // End of 1st FFT cycle.
      output_valid; // Output valid flag.

50 reg [3:0] pipeline_count; // Counts pipeline regs.
reg [AddressSize-1:0] q, t;
reg [1:0] r;
reg [wordlength-1:0] x1r_0_reg, x1i_0_reg,
55      xr_tmp2, // Output data reg, I.
      xi_tmp2; // Output data reg, Q.
reg [s12_wdlength-1:0] in_xr_tmp, in_xi_tmp;

```

```

      x1r_5, x1i_5,    // input register.
      x1r_6, x1i_6,
      x1r_7, x1i_7,
      x1r_8, x1i_8,
      x1r_9, x1i_9,
      x1r_10, x1i_10,
5
      x2r_0, x2i_0,    // Couples the I/Q data
      x2r_1, x2i_1,    // outputs from BF2I
      x2r_2, x2i_2,    // to the I/Q inputs of
      x2r_3, x2i_3,    // BF2II. Also connects
      x2r_4, x2i_4,    // the I/Q outputs of the
      x2r_5, x2i_5,    // complex multiplier
      x2r_6, x2i_6,    // to the inputs of the
      x2r_7, x2i_7,    // next radix 2^2 stage.
      x2r_8, x2i_8,
      x2r_9, x2i_9,
      x2r_10, x2i_10;
10
20  reg [wordlength-1:0] x1r_4_tmp, x1i_4_tmp, // Registered inputs
      x1r_5_tmp, x1i_5_tmp, // from RAM.
      x1r_6_tmp, x1i_6_tmp,
      x1r_7_tmp, x1i_7_tmp,
      x1r_8_tmp, x1i_8_tmp,
      x1r_9_tmp, x1i_9_tmp,
      x1r_10_tmp, x1i_10_tmp;
25
30  wire [s11_wdlength-1:0] x1r_11, x1i_11,    // Different bit-widths
      x2r_11, x2i_11; // for I/Q lines, but
      wire [s12_wdlength-1:0] x1r_12, x1i_12; // similar to the above.
35
40  wire [wordlength-1:0] ar_0, ai_0,    // Couples the I/Q data
      ar_1, ai_1,    // outputs of the
      ar_2, ai_2,    // previous radix 2^2
      ar_3, ai_3,    // stage into the
      ar_4, ai_4,    // complex multiplier
      ar_5, ai_5;    // of the next stage.
45
50  wire [c_wordlength-1:0] br_0, bi_0,    // Couples the I/Q
      br_1, bi_1,    // coefficient outputs
      br_2, bi_2,    // from the ROM demapper
      br_3, bi_3,    // to the complex
      br_4, bi_4,    // multiplier.
      br_5, bi_5;
55
      wire [wordlength-1:0] z2r_0, z2i_0,
      z2r_1, z2i_1,
      z2r_2, z2i_2,
      z2r_3, z2i_3;
      reg [wordlength-1:0] z2r_4, z2i_4,    // Registered outputs
      z2r_5, z2i_5,    // to RAM.
      z2r_6, z2i_6,
      z2r_7, z2i_7,
      z2r_8, z2i_8,
      z2r_9, z2i_9;

```

```

input      clk,          // Master clock.
           nrst,         // Power-up reset.
           in_2k8k,       // 2K mode active low.
           valid_in;     // Input data valid.
5    input [9:0]   in_xr,        // FFT input data, I.
           in_xi;        // FFT input data, Q.

input [wordlength-1:0] x1r_4, x1i_4,    // RAM output ports.
10   x1r_5, x1i_5,
     x1r_6, x1i_6,
     x1r_7, x1i_7,
     x1r_8, x1i_8,
     x1r_9, x1i_9,
     x1r_10, x1i_10;

15   input [c_wordlength-1:0] br_3, bi_3,
     br_4, bi_4;

output      out_ovf,      // Overflow flag.
20   enable_0,       // Enable clock 0.
     enable_1,       // Enable clock 1.
     enable_2,       // Enable clock 2.
     enable_3,       // Enable clock 3.
     valid_out,     // Output data valid.
25   ram_enable;

output [wordlength-1:0] out_xr,        // FFT output data, I.
           out_xi;        // FFT output data, Q.

30   output [wordlength-1:0] z2r_4, z2i_4,    // RAM input ports.
     z2r_5, z2i_5,
     z2r_6, z2i_6,
     z2r_7, z2i_7,
     z2r_8, z2i_8,
35   z2r_9, z2i_9,
     z2r_10, z2i_10;

output [rom_AddressSize-6:0] address_rom3;
output [rom_AddressSize-4:0] address_rom4;
40   output [AddressSize-1:0] ram_address;

// -----
//      Wire/register declarations.
45   //

wire [1:0]      control;      // clk decode.
wire [AddressSize-1:0] address,    // FFT main address bus.
50   s,             // Pipeline SRs to BFs.
     ram_address;    // RAM address bus.

wire [wordlength-1:0] x1r_0, x1i_0,    // Couples the I/Q data
55   x1r_1, x1i_1,    // outputs from the
     x1r_2, x1i_2,    // memory to the
     x1r_3, x1i_3,    // respective butterfly
     x1r_4, x1i_4,    // processors, via an

```

```

`timescale 1ns / 100ps

module fft_r22sdf    (in_xr,
5      in_xi,
      clk,
      nrst,
      in_2k8k,
      valid_in,
10     out_xr,
      out_xi,
      out_ovf,
      enable_0,
      enable_1,
      enable_2,
15     enable_3,
      valid_out,
      ram_address,
      ram_enable,
      address_rom3,
      address_rom4,
20     z2r_4, z2i_4, // RAM input ports.
      z2r_5, z2i_5, // Output data from this
      z2r_6, z2i_6, // module.
      z2r_7, z2i_7,
25     z2r_8, z2i_8,
      z2r_9, z2i_9,
      z2r_10, z2i_10,
      x1r_4, x1i_4, // RAM output ports.
      x1r_5, x1i_5, // Input data to this
30     x1r_6, x1i_6, // module.
      x1r_7, x1i_7,
      x1r_8, x1i_8,
      x1r_9, x1i_9,
      x1r_10, x1i_10,
35     br_3, bi_3,
      br_4, bi_4);

40   // -----
41   // Parameter definitions.
42   // -----
43
44   parameter wordlength = 12; // Data wordlength.
45   parameter c_wordlength = 10; // Coeff wordlength.
46   parameter AddressSize = 13; // Size of address bus.
47   parameter rom_AddressSize = 13; // ROM address bus size.
48   parameter mult_scale = 3; // Multiplier scaling:
49       // 1 = /4096, 2 = /2048,
50       // 3 = /1024, 4 = /512.
51
52   parameter s12_wdlength = 11; // Sectn 12 wordlength.
53   parameter s11_wdlength = 12; // Sectn 11 wordlength.
54       // s11 >= s12 >= wordlen

55   // -----
56   // Input/Output ports.
57   // -----

```

```

inc = 2'd0;
//-----
endcase

5   always @(posedge clk)
if (enable_3)
begin
  if (!rst || !rst) // out_address=0 at end of line or pwr Reset.
    out_address_tmp <= 0;
10  else
    out_address_tmp <= out_address_tmp + inc;

  // Only count if at the correct point on line 2.
  if (in_address[rom_AddressSize-3] & (~in_address[rom_AddressSize-4:0]))
15  count <= ((count == 2'd2) ? 2'd0 : count + 2'd1); // Only count to 2.
  else
    count <= 2'd0;
end

20 assign out_address = out_address_tmp;
endmodule

```

## Listing 12

// SccsId: %W% %G%

\*\*\*\*\*

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Author : Dawood Alam.

30 Description: Verilog code for a configurable 2K/8K radix  $2^2 + 2$ ,  
singlepath-delay-feedback, decimation in frequency,  
(r22+2sdf DIF) Fast Fourier Transform (FFT) processor. (RTL)

35 Notes : This FFT processor computes one pair of I/Q data points every 4  
fast clk cycles. A synchronous active-low reset flushes the  
entire pipeline and resets the FFT. Therefore the next pair of  
valid inputs are assumed to be the start of the active interval  
of the next symbol. There is a latency of 2048/8192 sample  
points + 7 slow clock cycles. This equates to  $(2048/8192 + 7)*4$   
40 fast clk cycles. When the out\_ovf flag is raised an overflow has  
occurred and saturation is performed on the intermediate  
calculation upon which the overflow has occurred. If the valid\_in  
flag is held low, the entire pipeline is halted and the  
valid\_out flag is also held low. valid\_out is also held low  
45 until the entire pipeline is full (after the above number of  
clock cycles).

To Do: RAM control (MUX),  
ROM lookup (quadrant lookup),  
50 Change BF code for unique saturation nets for synthesis.  
ovf\_detection (correct) register o/p  
ovf detection (correct) for mpy and BFs  
ROM/RAM test stuff.

55 \*\*\*\*\*\*/

```

    enable_3;

    output [rom_AddressSize-2:0] out_address;

5     wire [rom_AddressSize-2:0] out_address;
      wire [1:0]      line_number;
      wire         nrst;

10    reg [rom_AddressSize-2:0] out_address_tmp;
      reg [1:0]      inc, count;
      reg           rst;

// Decode which of the 4 lines are being addressed and assign it a line no.
// Only need upper two bits of in_address since 4 lines in sequence length.
15    assign line_number = {in_address[rom_AddressSize-1],
                         in_address[rom_AddressSize-2]};

// Check for end of line and force out_address to zero on next clock edge.
20    always @(in_address)
      if (in_address[rom_AddressSize-3:0] == {rom_AddressSize-2{1'b1}})
          rst = 0;
      else
          rst = 1;

25    // Check for line number and decode appropriate out_address using algorithm
// derived by studying coefficient tables for mpys M0, M1 and M2.
      always @(line_number or in_address or count)
      case (line_number)
//-----
30    2'd0: // LINE 0, inc by 2, then run the inc sequence 1,1,2,1,1,2...
      begin
          if (in_address[rom_AddressSize-3] & (~in_address[rom_AddressSize-4:0]))
              begin
                  if (count == 2'd1 | count == 2'd0)
35          inc = 2'd1;
                  else
                      inc = 2'd2;
                  end
                  else
                      inc = 2'd2;
              end
//-----
40    2'd1: // LINE 1, inc by 1.
      inc = 1;
//-----
45    2'd2: // LINE 2 inc by 3, (inc by 2 at N/4+1), (inc by 1 at N/2-1).
      begin
          if (in_address[rom_AddressSize-3:0] >= break_point3)
              inc = 2'd1;           // Third stage, inc by 1.
50          else if (in_address[rom_AddressSize-3:0] >= break_point2)
              inc = 2'd2;           // Second stage, inc by 2.
              else
                  inc = 2'd3;           // First stage, inc by 3.
      end
//-----
55    2'd3: // LINE 3, fixed at address 0.

```

```

7'd33:b_tmp1 =20'b1000001010_1110011100; //W60_128=-0.980785 -0.195090
7'd34:b_tmp1 =20'b1000000010_111001110; //W62_128=-0.995185 -0.098017
7'd88:b_tmp1 =20'b1000000001_111100111; //W63_128=-0.998795 -0.049068
7'd89:b_tmp1 =20'b1000000010_0000110010; //W66_128=-0.995185 +0.098017
5   7'd90:b_tmp1 =20'b1000001111_0001111100; //W69_128=-0.970031 +0.242980
7'd91:b_tmp1 =20'b1000100111_0011000100; //W72_128=-0.923880 +0.382683
7'd92:b_tmp1 =20'b1001001001_0100000111; //W75_128=-0.857729 +0.514103
7'd93:b_tmp1 =20'b1001110100_0101000101; //W78_128=-0.773010 +0.634393
7'd94:b_tmp1 =20'b1010101000_0101111011; //W81_128=-0.671559 +0.740951
10  7'd95:b_tmp1 =20'b1011100100_0110101010; //W84_128=-0.555570 +0.831470
7'd96:b_tmp1 =20'b1100100101_0111001111; //W87_128=-0.427555 +0.903989
7'd97:b_tmp1 =20'b1101101011_0111101010; //W90_128=-0.290285 +0.956940
7'd98:b_tmp1 =20'b1110110101_0111111010; //W93_128=-0.146730 +0.989177
default:b_tmp1 =20'b0111111111_0000000000; //W00_128=+1.000000 -0.000000
15  endcase

always @(posedge clk)
if (enable_3)
  b_tmp2 <= b_tmp1;
20
assign out_br = b_tmp2[c_wordlength*2-1:c_wordlength];
assign out_bi = b_tmp2[c_wordlength-1:0];

endmodule
25

```

Listing 11

```

// SccsId: %W% %G%
/****************************************************************************
30   Copyright (c) 1997 Pioneer Digital Design Centre Limited

Author : Dawood Alam.

Description: Verilog code for a lookup table decoder.
35
Notes : Used to generate addresses for each coefficient, based on the
        in_Address. Addresses are dependent on one of 4 rows
        (see figures) and on the sequence length (rom_AddressSize). Each
        row gives rise to a unique address sequence based on an
        algorithm. N refers to the index of the twiddle factor, NOT the
        absolute address. Breakpoints determine where inc values change
40  on line 2.

*****
45
`timescale 1ns / 100ps

module fft_coeff_dcd (clk, enable_3, in_address, out_address, nrst);

50  parameter rom_AddressSize = 1; // Twice ROM address.
parameter break_point2 = 1; // 2nd break pt line 2
parameter break_point3 = 1; // 3rd break pt line 2

55  input [rom_AddressSize-1:0] in_address;
      input      clk,
                  nrst,
```

7'd49:b\_tmp1 =20'b0110001100\_1010111011; //W14\_128=+0.773010 -0.634393  
 7'd50,  
 7'd72:b\_tmp1 =20'b0101111011\_1010101000; //W15\_128=+0.740951 -0.671559  
 7'd11,  
 5 7'd51:b\_tmp1 =20'b0101101010\_1010010110; //W16\_128=+0.707107 -0.707107  
 7'd52:b\_tmp1 =20'b0101011000\_1010000101; //W17\_128=+0.671559 -0.740951  
 7'd12,  
 7'd73,  
 7'd53:b\_tmp1 =20'b0101000101\_1001110100; //W18\_128=+0.634393 -0.773010  
 10 7'd54:b\_tmp1 =20'b0100110001\_1001100101; //W19\_128=+0.595699 -0.803208  
 7'd13,  
 7'd55:b\_tmp1 =20'b0100011100\_1001010110; //W20\_128=+0.555570 -0.831470  
 7'd74,  
 7'd56:b\_tmp1 =20'b0100000111\_1001001001; //W21\_128=+0.514103 -0.857729  
 15 7'd14,  
 7'd57:b\_tmp1 =20'b0011110001\_1000111100; //W22\_128=+0.471397 -0.881921  
 7'd58:b\_tmp1 =20'b0011011011\_1000110001; //W23\_128=+0.427555 -0.903989  
 7'd15,  
 7'd75,  
 20 7'd59:b\_tmp1 =20'b0011000100\_1000100111; //W24\_128=+0.382683 -0.923880  
 7'd60:b\_tmp1 =20'b0010101100\_1000011110; //W25\_128=+0.336890 -0.941544  
 7'd16,  
 7'd61:b\_tmp1 =20'b0010010101\_1000010110; //W26\_128=+0.290285 -0.956940  
 7'd76,  
 25 7'd62:b\_tmp1 =20'b0001111100\_1000001111; //W27\_128=+0.242980 -0.970031  
 7'd17,  
 7'd63:b\_tmp1 =20'b0001100100\_1000001010; //W28\_128=+0.195090 -0.980785  
 7'd64:b\_tmp1 =20'b0001001011\_1000000110; //W29\_128=+0.146730 -0.989177  
 7'd18,  
 30 7'd77,  
 7'd65:b\_tmp1 =20'b0000110010\_1000000010; //W30\_128=+0.098017 -0.995185  
 7'd66:b\_tmp1 =20'b0000011001\_1000000001; //W31\_128=+0.049068 -0.998795  
 7'd19:b\_tmp1 =20'b0000000000\_1000000000; //W32\_128=+0.000000 -1.000000  
 7'd78:b\_tmp1 =20'b1111100111\_1000000001; //W33\_128=-0.049068 -0.998795  
 35 7'd20:b\_tmp1 =20'b1111001110\_1000000010; //W34\_128=-0.098017 -0.995185  
 7'd79,  
 7'd21:b\_tmp1 =20'b1110011100\_1000001010; //W36\_128=-0.195090 -0.980785  
 7'd22:b\_tmp1 =20'b1101101011\_1000010110; //W38\_128=-0.290285 -0.956940  
 7'd80:b\_tmp1 =20'b1101010100\_1000011110; //W39\_128=-0.336890 -0.941544  
 40 7'd23:b\_tmp1 =20'b1100111100\_1000100111; //W40\_128=-0.382683 -0.923880  
 7'd81,  
 7'd24:b\_tmp1 =20'b1100001111\_1000111100; //W42\_128=-0.471397 -0.881921  
 7'd25:b\_tmp1 =20'b1011100100\_1001010110; //W44\_128=-0.555570 -0.831470  
 7'd82:b\_tmp1 =20'b1011001111\_1001100101; //W45\_128=-0.595699 -0.803208  
 45 7'd26:b\_tmp1 =20'b1010111011\_1001110100; //W46\_128=-0.634393 -0.773010  
 7'd83,  
 7'd27:b\_tmp1 =20'b1010010110\_1010010110; //W48\_128=-0.707107 -0.707107  
 7'd28:b\_tmp1 =20'b1001110100\_1010111011; //W50\_128=-0.773010 -0.634393  
 7'd84:b\_tmp1 =20'b1001100101\_1011001111; //W51\_128=-0.803208 -0.595699  
 50 7'd29:b\_tmp1 =20'b1001010110\_1011100100; //W52\_128=-0.831470 -0.555570  
 7'd85,  
 7'd30:b\_tmp1 =20'b1000111100\_1100001111; //W54\_128=-0.881921 -0.471397  
 7'd31:b\_tmp1 =20'b1000100111\_1100111100; //W56\_128=-0.923880 -0.382683  
 7'd86:b\_tmp1 =20'b1000011110\_1101010100; //W57\_128=-0.941544 -0.336890  
 55 7'd32:b\_tmp1 =20'b1000010110\_1101101011; //W58\_128=-0.956940 -0.290285  
 7'd87,

Description: Verilog code for 128 hardwired coefficients in a lookup table, of which 64 are unique values.

5      Notes : Used to store complex Twiddle factors. 128 point FFT twiddle  
       factor coefficients (Radix 4+2). Coefficients stored as  
       non-fractional 10 bit integers. Real Coefficient (cosine value)  
       is coefficient high-byte. Imaginary Coefficient (sine value) is  
       coefficient low-byte. Coefficient addresses are delayed by a  
 10     pipeline depth of 3, i.e. equivalent to case table values being  
       advanced by 3.

\*\*\*\*\*\*/

```

15 `timescale 1ns / 100ps

module fft_hardwired_lu2 (clk, enable_3, address, out_br, out_bi);

20 parameter      c_wordlength = 10; // Coeff wordlength.
parameter      rom_AddressSize = 7; // Address bus size.

25 input         clk,
              enable_3;
input [rom_AddressSize-1:0] address;

30 output [c_wordlength-1:0] out_br, out_bi;
reg [c_wordlength*2-1:0] b_tmp1,
                        b_tmp2;

35 always @(address)
case (address)
  7'd36:b_tmp1 =20'b0111111111_1111001111; //W01_128=+0.998795 -0.049068
  7'd4,
  7'd37:b_tmp1 =20'b011111110_1111001110; //W02_128=+0.995185 -0.098017
  7'd38,
  7'd68:b_tmp1 =20'b0111111010_1110110101; //W03_128=+0.989177 -0.146730
  7'd5,
  7'd39:b_tmp1 =20'b0111110110_1110011100; //W04_128=+0.980785 -0.195090
  40 7'd40:b_tmp1 =20'b0111110001_1110000100; //W05_128=+0.970031 -0.242980
  7'd6,
  7'd41,
  7'd69:b_tmp1 =20'b0111101010_1101101011; //W06_128=+0.956940 -0.290285
  7'd42:b_tmp1 =20'b0111100010_1101010100; //W07_128=+0.941544 -0.336890
  45 7'd7,
  7'd43:b_tmp1 =20'b0111011001_1100111100; //W08_128=+0.923880 -0.382683
  7'd44,
  7'd70:b_tmp1 =20'b0111001111_1100100101; //W09_128=+0.903989 -0.427555
  7'd8,
  50 7'd45:b_tmp1 =20'b0111000100_1100001111; //W10_128=+0.881921 -0.471397
  7'd46:b_tmp1 =20'b0110110111_1011111001; //W11_128=+0.857729 -0.514103
  7'd9,
  7'd47,
  7'd71:b_tmp1 =20'b0110101010_1011100100; //W12_128=+0.831470 -0.555570
  55 7'd48:b_tmp1 =20'b0110011011_1011001111; //W13_128=+0.803208 -0.595699
  7'd10,
```

```

parameter      c_wordlength = 10; // Coeff wordlength.
parameter      rom_AddressSize = 5; // Address bus size.

5   input      clk,
      enable_3;
input [rom_AddressSize-1:0] address;
output [c_wordlength-1:0] out_br, out_bi;
10  reg [c_wordlength*2-1:0] b_tmp1,
      b_tmp2;

15  always @(address)
case (address)
  5'd5,
  5'd14:b_tmp1 = 20'b0111011001_1100111100;// W02_32 = +0.923880 -0.382683
  5'd6,
  5'd16:b_tmp1 = 20'b0101101010_1010010110;// W04_32 = +0.707107 -0.707107
20  5'd7,
  5'd18,
  5'd22:b_tmp1 = 20'b0011000100_1000100111;// W06_32 = +0.382683 -0.923880
  5'd8: b_tmp1 = 20'b000000000000_100000000000;// W08_32 = +0.000000 -1.000000
  5'd9: b_tmp1 = 20'b1100111100_1000100111;// W10_32 = -0.382683 -0.923880
25  5'd10,
  5'd24:b_tmp1 = 20'b1010010110_1010010110;// W12_32 = -0.707107 -0.707107
  5'd11:b_tmp1 = 20'b1000100111_1100111100;// W14_32 = -0.923880 -0.382683
  5'd13:b_tmp1 = 20'b0111110110_1110011100;// W01_32 = +0.980785 -0.195090
  5'd15,
30  5'd21:b_tmp1 = 20'b0110101010_1011100100;// W03_32 = +0.831470 -0.555570
  5'd17:b_tmp1 = 20'b0100011100_1001010110;// W05_32 = +0.555570 -0.831470
  5'd19:b_tmp1 = 20'b00011100100_1000001010;// W07_32 = +0.195090 -0.980785
  5'd23:b_tmp1 = 20'b1110011100_1000001010;// W09_32 = -0.195090 -0.980785
  5'd25:b_tmp1 = 20'b1000001010_1110011100;// W15_32 = -0.980785 -0.195090
35  5'd26:b_tmp1 = 20'b1000100111_0011000100;// W18_32 = -0.923880 +0.382683
  5'd27:b_tmp1 = 20'b1011100100_0110101010;// W21_32 = -0.555570 +0.831470
  default: b_tmp1 = 20'b0111111111_0000000000;// W00_32 = +1.000000 -0.000000
endcase

40  always @(posedge clk)
if (enable_3)
  b_tmp2 <= b_tmp1;

45  assign out_br = b_tmp2[c_wordlength*2-1:c_wordlength];
assign out_bi = b_tmp2[c_wordlength-1:0];

endmodule

```

// SccsId: %W% %G%  
\*\*\*\*\*

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Author : Dawood Alam.

```

module fft_hardwired_lu0 (clk, enable_3, address, out_br, out_bi);

5   parameter      c_wordlength = 10; // Coeff wordlength.
   parameter      rom_AddressSize = 3; // Address bus size.

   input          clk,
   enable_3;
   input [rom_AddressSize-1:0] address;

10  output [c_wordlength-1:0] out_br, out_bi;

   reg [c_wordlength*2-1:0] b_tmp1,
                           b_tmp2;

15  always @(address)
  case (address)
    3'd6: b_tmp1 = 20'b0000000000_1000000000; // W2_8 = +0.000000 -1.000000
    3'd0: b_tmp1 = 20'b0101101010_1010010110; // W1_8 = +0.707107 -0.707107
    3'd2: b_tmp1 = 20'b1010010110_1010010110; // W3_8 = -0.707107 -0.707107
20  default:b_tmp1 = 20'b0111111111_0000000000; // W0_8 = +1.000000 -0.000000
  endcase

25  always @(posedge clk)
  if (enable_3)
    b_tmp2 <= b_tmp1;

30  assign out_br = b_tmp2[c_wordlength*2-1:c_wordlength];
  assign out_bi = b_tmp2[c_wordlength-1:0];

endmodule

```

## Listing 9

```

35 // SccsId: %W% %G%
*****Copyright (c) 1997 Pioneer Digital Design Centre Limited
Author : Dawood Alam.
40 Description: Verilog code for 32 hardwired coefficients in a lookup table, of
which 16 are unique values.

45 Notes : Used to store complex Twiddle factors. 32 point FFT twiddle
factor coefficients (Radix 4+2). Coefficients stored as
non-fractional 10 bit integers. Real Coefficient (cosine value)
is coefficient high-byte. Imaginary Coefficient (sine value) is
coefficient low-byte. Coefficient addresses are delayed by a
50 pipeline depth of 4, i.e. equivalent to case table values being
advanced by 4.

*****
`timescale 1ns / 100ps
55 module fft_hardwired_lu1 (clk, enable_3, address, out_br, out_bi);

```

```

output [wordlength-1:0] out_xr,      // SR output data I.
      out_xi;      // SR output data Q.

5   reg [wordlength-1:0] shift_r [length-1:0]; // SR for I data.
    reg [wordlength-1:0] shift_i [length-1:0]; // SR for Q data/

    wire [wordlength-1:0] out_xr,
        out_xi;
    wire      clk,
10   enable_3;
integer      i;

15  always @ (posedge clk)
if (enable_3)
begin
    for (i = (length-1); i >= 0; i = i - 1)
begin
    if (i == 0)
begin
20    shift_r[0] <= in_xr;      // Force input I to SR.
        shift_i[0] <= in_xi;      // Force input Q to SR.
    end
    else
begin
25    shift_r[i] <= shift_r[i-1]; // Shift data I once.
        shift_i[i] <= shift_i[i-1]; // Shift data Q once.
    end
end
end
30  assign out_xr = shift_r[length-1];
    assign out_xi = shift_i[length-1];
endmodule

```

## 35 Listing 8

```

// SccsId: %W% %G%
*****
40  Copyright (c) 1997 Pioneer Digital Design Centre Limited
Author : Dawood Alam.

45  Description: Verilog code for 8 hardwired coefficients in a lookup table, of
which 4 are unique values.

Notes : Used to store complex Twiddle factors. 8 point FFT twiddle factor
coefficients (Radix 4+2). Coefficients stored as non-fractional
10 bit integers. Real Coefficient (cosine value) is coefficient
high-byte. Imaginary Coefficient (sine value) is coefficient
50  low-byte. Coefficient addresses are delayed by a pipeline depth
of 5, i.e. equivalent to case table values being advanced by 5.

*****
55  `timescale 1ns / 100ps

```

```

// Register ovf outputs before final OR, else whole complex multiplier is
// treated as combinational, and the intermediate pipeline reg is ignored.
// always @(posedge clk)
// if (enable_0 || enable_1 || enable_2)
5   ovf_tmp2 <= ovf_tmp0;

always @(posedge clk)
ovf_tmp3 <= ovf_tmp1;

10 assign out_ovf = ovf_tmp2 || ovf_tmp3;

`ifdef OVERFLOW_DEBUG_LOW_LEVEL
// Debug code to display overflow output of a particular adder.
// Concurrently monitor overflow flag and halt on overflow.
15 always @(posedge clk)
if (out_ovf)
begin
  if (ovf_tmp2) $display("ovf_tmp0 on complex multiplier = ",ovf_tmp2);
  if (ovf_tmp3) $display("ovf_tmp1 on complex multiplier = ",ovf_tmp3);
20   $stop;
end
else
endif

25 assign out_cr = cr_tmp;
assign out_ci = ci_tmp;

endmodule

```

30

## Listing 7

```

// SccsId: %W% %G%
*****
35 Copyright (c) 1997 Pioneer Digital Design Centre Limited
Author : Dawood Alam.

Description: Verilog code for a dual-port FIFO with complex data store. (RTL)
40 Notes : A variable bitwidth FIFO shift register for intermediate I/Q
calculations.
*****
45 `timescale 1ns / 100ps

module fft_sr_iq (clk, enable_3, in_xr, in_xi, out_xr, out_xi);

50 parameter wordlength = 1; // Data wordlength I/Q.
parameter length = 1; // Shift reg length.

input clk, // Master clock;
      enable_3; // Enable on clock 3.
55 input [wordlength-1:0] in_xr, // SR input data, I.
      in_xi; // SR input data, Q.

```

```

begin
    coeff_tmp1 = in_ar_tmp;
    sum_tmp0 = store_tmp;
    end
5    endcase

abri_tmp3 = {{wordlength{abri_tmp2[wordlength-1]}},abri_tmp2}; // extnd
coeff_tmp2 = {{wordlength{coeff_tmp1[wordlength-1]}},coeff_tmp1};// extnd
mpy_tmp2 = (abri_tmp3 * coeff_tmp2);

10   mpy_tmp1 = mpy_tmp2[wordlength*2-mult_scale:wordlength-(mult_scale-1)];

    if (c4)
        {ex_reg1,sum_tmp2} = sum_tmp0 - mpy_tmp1 - mpy_tmp2[wordlength-mult_scale];
15   else
        {ex_reg1,sum_tmp2} = mpy_tmp1 + sum_tmp0 +
mpy_tmp2[wordlength-mult_scale];

ovf_tmp1 = (c4 ^ mpy_tmp1[wordlength-1]) && // Overflow check.
20   sum_tmp0[wordlength-1] && // Deals with a
~sum_tmp2[wordlength-1] || // +/- input.
~(c4 ^ mpy_tmp1[wordlength-1]) &&
~sum_tmp0[wordlength-1] &&
sum_tmp2[wordlength-1];
25   if (ovf_tmp1) // Saturate logic.
        sum_tmp1 = (ex_reg1) ? {1'b1,{wordlength-1{1'b0}}}: {1'b0,{wordlength-1{1'b1}}};
    else
        sum_tmp1 = sum_tmp2;
30   end

// Pipeline registers for I/Q data paths and intermediate registers.
always @ (posedge clk)
begin
35   if (enable_2) // Enable on 2nd clock.
    acc_tmp <= sum_tmp1; // Temp store.

    if (enable_3) // Enable on 3rd clock.
    cr_tmp <= acc_tmp; // Pipeline reg cr
40   if (enable_3) // Enable on 3rd clock.
    ci_tmp <= sum_tmp1; // Pipeline reg ci

    if(enable_1)
45   store_tmp <= sum_tmp1; // Temp store.

    if (enable_2)
    in_ar_tmp <= in_ar; // Reg i/p to mpy.

50   if (enable_1)
    in_ai_tmp <= in_ai; // Reg i/p to mpy.

    if (enable_0 || enable_1 || enable_2)
    abri_tmp2 <= abri_tmp1; // Pipeline reg.
55   end

```